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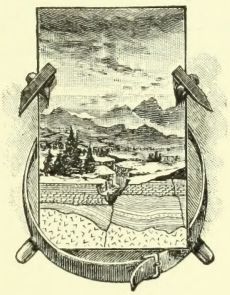

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CONTENTS

Water-supply paper 224; Some desert watering places in southeastern California, etc.
Same 225; Ground waters of Indio region, Cal., etc.
Same 226; Pollution of streams by sulphite pulp waste.
Same 227; Geology and underground waters of South Dakota.
Same 228; Investigations in Yukon-Tanana region, Alaska.
Same 229; Disinfection of sewage and sewage filter effluents.
Same 230; Surface water supply of Nebraska.

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
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WATER-SUPPLY PAPER 224

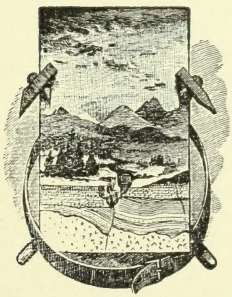
SOME DESERT WATERING PLACES

IN

SOUTHEASTERN CALIFORNIA AND SOUTHWESTERN NEVADA

BY

WALTER C. MENDENHALL



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CONTENTS.

	Page.
Introduction	5
Area considered	5
Mineral resources and industrial developments	6
Sources of data	7
Physical features	8
General character of the region	8
Death Valley basin	9
Soda Lake	10
Salton Sink	10
A great trough	10
Fault lines	11
Climate	11
Water supply	13
Origin	13
Rivers	13
Springs	15
Finding water	16
Camping places	16
Mountain springs and tanks	17
Dry lakes	17
Geologic hints	18
Vegetation as a guide	20
Hints on desert traveling	21
Teams, hay, and grain	21
Tools	22
Clothing, bedding, etc	22
Provisions	23
Water	23
Fuel	24
Getting lost	24
Main routes of travel	25
Starting points	25
Frémont's trail	25
Old Spanish trail	26
Mohave-Keeler route	26
Death Valley routes	26
Bullfrog routes	27
Searchlight route	28
Needles-Parker route	28
Amboy-Dale route	28
Mecca-Dale route	28
Victorville routes	28
Banning-Dale route	29

Page.
Irrigating and artesian waters 29
Irrigated areas 29
Artesian waters 29
Description of springs 30
Symbols used 30
California 31
Nevada 87
Index 95

ILLUSTRATIONS.

Page.
PLATE I. Map of southeastern California and southwestern Nevada, showing location of watering places ..... In pocket.
II. *A*, Death Valley, looking north toward the Black Mountains; *B*, Out West Well 10
III. *A*, Kane's Wells; *B*, Coyote Well 60
IV. *A*, Providence Wells; *B*, Box S ranch 66

SOME DESERT WATERING PLACES IN SOUTHEASTERN CALIFORNIA AND SOUTHWESTERN NEVADA.

By Walter C. Mendenhall.

INTRODUCTION.

AREA CONSIDERED.

This report relates especially to the southwestern part of the Great Basin—the portion of it that is bounded on the west by the Sierra Nevada and Sierra Madre, on the east by Colorado River, on the south by Mexico, and on the north by the parallel between Tps. 4 and 5 S. of the Mount Diablo base line. It includes the arid portions of southeastern California and those adjacent parts of Nevada that are most easily reached from California points. This region is known generally to the dwellers in the less arid districts west of the Sierra as "the desert," but local names are applied to its various subdivisions. Among the more important of the subdivisions are the Colorado and Mohave deserts and the Death Valley region.

The Colorado Desert is that definitely limited arid valley which extends from San Gorgonio Pass southward to the Gulf of California, and includes the depression known as the "Salton Sink." The Mohave Desert lies farther north and its boundaries are not so definite, but it includes much the greater part of San Bernardino County and the eastern portions of Los Angeles and Kern counties, Cal. The Death Valley region, which lies north of the Mohave Desert, stretches eastward from the Sierra Nevada, covering a large part of Inyo County, Cal., and extending into Nevada. It is named from its central feature, Death Valley, the lowest point on the continent.

The desert region outlined above and shown on the accompanying map (Pl. I) covers an area of about 68,000 square miles. The wells and springs within it are few in number and are very irregularly distributed. In some districts watering places occur in groups; in other tracts they are 30 to 50 miles apart. So irregular is their distribution that it is important that they should be located as definitely as possible and described for the benefit of prospectors and other travelers. The scarcity of water and the importance of a knowledge

of its whereabouts are indicated by its cost in many of the mining camps and by the frequency with which the press records instances of death from thirst in the more remote parts of the desert.

MINERAL RESOURCES AND INDUSTRIAL DEVELOPMENTS.

The mineral resources of the region under discussion are being developed with a rapidity that is attracting general attention. The most important of these resources is gold, and the present intense interest in the desert is in large part due to the discovery and development within it of mines that are heavy producers of this metal.

The resources of the region, however, are not confined to the precious metals, but comprise a wide range of mineral products of economic value. Among these may be mentioned several valuable salts, including borax, soda, gypsum, and common salt; building material, including marble, onyx, brick clays, and cements; baser metals, like copper, iron, and lead; and gems, among which are turquoise and opal. Just west of the desert proper, in the mountains of San Diego and Riverside counties, precious tourmaline, kunzite, and the rarer garnets have been discovered in connection with the pegmatite dikes there. These products are widely distributed throughout the desert counties. The existence of some of them in commercial quantities and available form is as yet problematic, although their occurrence is known, while important industries are already based on others.

The building of railroads in the desert within the last three years and the projection of other lines not yet built indicate for the future a marked increase in the mineral output of this region. The Atchison, Topeka and Santa Fe Railway, generally known in the West as the Santa Fe, has one branch extending from Goffs, on its main line, northward to Ivanpah, a distance of about 50 miles; another from Ludlow southward 7 miles to Stedman; and a third running northward from Kramer to the mining camps at Randsburg and Johannesburg, a distance of 25 miles. A road has also been built from Ludlow to Bullfrog, Nev., with a branch to the Lila C. borax mines.

The Santa Fe is also constructing a road from Wickenberg, Ariz., to Parker, on Colorado River, and thence to Bengal, Cal., on the main line. This particular work is intended to correct the alignment of the transcontinental line, and to reduce grades and shorten the distance between Los Angeles and Chicago.

The San Pedro, Los Angeles and Salt Lake Railroad has completed a road from Las Vegas, Nev., to Bullfrog and Goldfield, Nev. Its main line is in operation from Daggett northeastward across the intervening deserts to Ogden, Utah, and is giving active stimulus to gold, silver, and lead mining. The Southern Pacific has a branch on the Colorado Desert, running from Imperial Junction southward

to the Imperial Irrigation Colony lands, and across the boundary into Mexico.

A line is being built that will unite the Southern Pacific branch at Keeler, on the east side of Owens Lake, with Mohave, near the southern edge of the Mohave Desert. Other lines are also projected which, if constructed, will connect Bullfrog directly with Los Angeles.

This unusual activity in railroad work, due in part to recent mining developments, has so stimulated prospecting that there is a large influx of strangers, many of whom do not fully realize the danger of traveling through an arid region in which springs are few and far between. The dissemination of information concerning the locations of known watering places and the possibilities for locating and developing water at other favorable points is therefore an urgent need. To meet this need the following report has been written and the map that accompanies it has been prepared.

SOURCES OF DATA.

The larger part of these data was compiled by Gilbert E. Bailey, who for several years has been obliged to traverse repeatedly many of the main desert roads and trails. At the outset of each trip it has been necessary to select, so far as possible, lines of travel along which water could be found, and to decide on springs that would be suitable sites for camps from which to penetrate the surrounding region.

It was not originally expected that the data thus slowly accumulated for personal use would be assembled for publication. The records are therefore by no means complete, nor are they of uniform value, for Mr. Bailey's acquaintance with some districts in the desert is more intimate than with others. Knowledge of watering places in this region is vital, and it is hoped that even the incomplete information assembled in the following pages will be useful.

In making the generalized base map (Pl. I) on which the location of the wells and springs is shown, data differing greatly in value and accuracy have of necessity been used. For the region from Death Valley northward and for the southwestern part of the area, including the Colorado Desert, the later topographic sheets of the United States Geological Survey are available and furnish satisfactory data. For the area along Colorado River from Needles northward old reconnaissance maps issued by the Survey were utilized. Of the region from the Colorado Desert and the Sierra Madre northward to Death Valley no satisfactory surveys have been made, and dependence has necessarily been placed on Land Office maps, railway surveys, and the various general, more or less inaccurate maps that have appeared from time to time. Probably the best of these—certainly

the one which is most highly regarded by prospectors and desert travelers generally—is the Fred T. Perris map of Riverside and San Bernardino counties. With such corrections as it has been found possible to make upon it, this map has been largely followed. In the desert portions of Riverside County especially, for which almost no late data exist, the Perris map is still the best guide. Developments, especially railroad surveys and construction, have given the information necessary for some changes in the northern portion of the area covered by it.

A number of the principal roads through the desert are indicated on the map. They are not surveyed, so that only approximate locations are possible, but these at least indicate the usual routes of travel.

The descriptions of the springs and watering places have been taken largely from the notes of Mr. Bailey. A large proportion of them have been visited at various times, but descriptions of others have been supplied by other desert travelers. R. H. Chapman, topographer, United States Geological Survey, has supplied notes on a number of wells and springs in the Amargosa district, with which he is familiar; C. A. Pinkham has aided with information concerning the Colorado Desert region; C. S. Alverson, of San Diego, has also contributed notes on this area; and many miners and prospectors have supplied information with which it is not possible to credit them individually.

On the whole, it is believed that fairly adequate and accurate descriptions are given of most of the better known and more accessible springs and wells, and that many of those which are less well known are included. Of course, numbers of springs exist in the higher mountain ranges of the desert that are known only to prospectors who are familiar with the details of these ranges. These watering places, however, are inaccessible to the casual traveler. The valley wells and springs, or at least those accessible from the most used highways, are the ones on which he must depend. It is hoped that the greater number of these are described in the succeeding pages. The data will be found more complete for the northern than the southern part of the region mapped (Pl. I).

PHYSICAL FEATURES.

GENERAL CHARACTER OF THE REGION.

The arid region lying between Colorado River and the Sierra of California shows a marked contrast in nearly all its physical conditions and scenic features with the region lying west of the great range.

To the geographer the most striking characteristic of the country east of the base of the Sierra Nevada is the fact that it is a region of

interior drainage. For this reason it is known as the "Great Basin." No streams that rise within it carry contributions to the ocean, but all the snow and rain that falls inside the rim of the basin is returned to the atmosphere by evaporation, either directly from the soil or after it has found its way into some of the lakes or sinks that occupy depressions in the irregular surface.

Some of the valleys or plains that separate the mountain ranges are absolute deserts, totally destitute of water, and treeless for a space representing many days' journey, the gray sagebrush alone giving life to the landscape. Each of the main desert basins includes a large area in which the land slopes toward a central depression, and each has a main drainage way through which flows an intermittent stream whose bed is dry most of the time along the greater portion of its course.

Many of the valleys have in their lowest depressions playas, or mud plains, left by the evaporation of intermittent lakes, and some of these are of great extent. Portions of some of the valleys have become incrusted to a depth of several inches with alkaline salts, which cover the surface as an efflorescence and present the appearance of drifting snow. Most of the permanent lakes into which some of the surface drainage finds its way are saline and alkaline. Their shores are desert wastes, shunned by animals and by all forms of life except salt-loving plants. The floor of the desert is dotted with many other smaller sinks or depressions that have no outlet and no inflow except during the rare desert storms. These are known locally as "dry lakes," "borax lakes," "salt lakes," "alkali marshes," etc.

DEATH VALLEY BASIN.

Death Valley Basin (Pl. II, *A*) is the sink of the Amargosa (Spanish for "bitter"), a name that was given to the river by Gen. J. C. Frémont in 1844. This stream, which is dry for the greater part of the time throughout much of its course, rises in a group of springs that lie about 17 miles northeast of the town of Bullfrog, Nev., in Oasis Valley. Its course is a little east of south until it passes Franklin Dry Lake; thence it flows southward through a deep canyon into South Death Valley. There it turns to the west and north, and is finally lost near Saratoga Springs. The Amargosa is about 140 miles long. It repeatedly disappears and reappears, flowing a short distance and then sinking, its water being absorbed by the sands until its channel crosses a ledge of bed rock, when it again emerges to view. Its water, which is potable near its source, percolates slowly downstream through the sands and takes up increasing quantities of alkaline salts from the soil, so that when it comes to the surface along its lower course, the water is charged with these salts, and though to

the eye it may appear potable, is unsafe to drink. This condition prevails only along the middle and lower courses of the stream. It is worse during flood periods, when quantities of surface alkali from along the banks of the stream are taken into solution. Near its source, where the water first rises in the springs, it is of excellent quality.

In going toward any point of the compass from Death Valley it is found that the floor of the basin gradually rises. In traveling southward one passes over low divides and gradually descends to Soda Lake, the sink of Mohave River. From Soda Lake the ground rises toward the east to the New York Mountains. Beyond these the drainage is toward Colorado River. West of Death Valley, the floor of the desert, above which several high ranges stand, gradually rises to the foot of the Sierra Nevada.

SODA LAKE.

Soda Lake is the sink of Mohave River, which rises in the San Bernardino Mountains and flows to Barstow, and thence northeastward to this sink. The river is over 100 miles long, but except during the flood season there is little surface flow save where ledges of rock athwart its course force the water to the surface.

SALTON SINK.

The Salton Sink, the lowest point of the Colorado Desert, was a part of the Gulf of California in comparatively recent geologic time, but it has been separated from the present gulf by the growth of the delta of Colorado River. Normally it receives only the occasional overflow from distributaries of this river, but in 1904 the Colorado was largely diverted to it, and only recently (1907) has that river been confined to its proper channel. The sink, therefore, is now partially filled by a lake with an area of nearly 500 square miles, which will probably not dry away completely for fifteen or twenty years.

A GREAT TROUGH.

The most important sinks of the desert form a more or less continuous group along a northwest-southeast line, which may be spoken of as the Great Trough.

The Death Valley axis is about 150 miles long, and extends from the north end of the valley southeastward to Silurian Dry Lake. There begins the sink of the Mohave Basin, which extends southward through Soda Lake and the Devil's Playground to Bristol, Cadiz, and Danby dry lakes, a distance of over 125 miles. It is separated from the Death Valley trough only by the low divide between Silurian Lake and Silver Lake, which are less than 15 miles apart.

A. DEATH VALLEY, LOOKING NORTH TOWARD THE BLACK MOUNTAINS.

B. OUT WEST WELL.

The trough of the Colorado Desert extends from San Gorgonio Pass southeastward through the Salton Sink to the Gulf of California. It is separated from the Mohave Basin by the San Bernardino, Cottonwood, Chuckwalla, and Chocolate mountains, and so forms an overlapping parallel axis of depression. This great axis is known to be closely related to widely extended geologic structures, and it is probable that the Death Valley axis has been similarly determined.

In addition to these major controlling depressions, the entire desert area consists of a series of more or less nearly parallel ranges and intervening minor desert valleys. In the northern part of the area the trend of these features is nearly north and south, and in the southern part the trend swings to the southeast; but in the intermediate region there is an area of confused, broken ranges in which definite trends seem to be lacking.

FAULT LINES.

It is well known that the eastern front of the Sierra Nevada is a great fault scarp, but it is perhaps less generally known that the north face of the San Gabriel Mountains is a similar structural line, which extends southeastward through Cajon and San Gorgonio passes and into the Colorado Desert. It is regarded as probable, too, that the great trough which has been described as extending northwest and southeast through the desert, along the line of the greater sinks, owes its origin to crustal movement. The basin-range type of structure, the tilted block first recognized by Gilbert, involves faulting along the uplifted edge, and recent geologic work in the desert has proven the existence of much faulting of the block type in the Bullfrog district.[a] It is not unlikely that when structural details shall have been worked out many of the strongest of the desert springs will be found along these fault lines, and that their waters will prove to be of deep origin and independent of local rainfall and local drainage. It is difficult otherwise to account for many of the springs.

CLIMATE.

The physical feature that exercises the greatest control over the climate of the Southwest is the great Sierra, which gives rain to the lands that lie west of it and withholds it from the desert to the east. The winds, which are moist and cool along the coast, shed their moisture upon the high mountains, and are dry when they reach the interior, where they absorb moisture from both the soil and the vegetation.

[a] Bull. U. S. Geol. Survey No. 303, 1907, pp. 50–52.

The climatic characteristics of the desert are its excessive summer heat and its dryness. The temperature rises occasionally to 125° F. in the shade, rarely falls below 70° at any time during the five hot months, and will average over 90° during this period. Exceptionally in the lowest points, as at Salton and in Death Valley, the shade temperature reaches 129° or 130°. During these periods of excessive heat men exposed to the sun's rays without water quickly perish.

The air is usually not stagnant, but is in active motion. Gales of a few hours' duration are common, and some of them bring sand storms. Rain may fall frequently in the mountains and occasionally in the valleys, and clouds are by no means rare, yet the heat and the wind together keep the surface very dry and the relative humidity low.

Cloud-bursts—concentrated storms of great severity—sometimes take place suddenly in the mountains, in the hottest weather. A cloud may form about a peak, quickly grow dense and black, and give a terrifying electric display. The lightning is followed by a torrent of rain, the character of the resulting flood depending on the relation of the storm to the topography. If it is concentrated in a canyon the result is a violent and spectacular flood wave, of great erosive and transporting power. If it is spread over an open slope, a slower moving and less destructive sheet flood follows the rain. Practically all of the desert erosion is accomplished during brief storms of this kind. Passengers on the railroads through New Mexico, Arizona, and eastern California have occasionally had experience with these cloud-bursts, and have appreciated the force and violence of the floods that result.

At a few points on the desert meteorological observations are made by volunteer observers for the United States Weather Bureau. The following tables will give an idea of the annual temperature and rainfall at a number of widely scattered points.

Temperature at 10 stations in California.

	1903.[a]			1904.[b]			1905.[c]		
	Annual mean.	Maximum.	Minimum.	Annual mean.	Maximum.	Minimum.	Annual mean.	Maximum.	Minimum.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
Bagdad	72.6	113	25	71.6	110	30	.....	119	33
Barstow	62.4	110	24	66.8	109	30	65.2	111	18
Bishop	55.1	98	4	56.1	97	12	55.0	99	8
Imperial	74.6	124	26	.....	115	28	71.5	124	22
Indio	.....	118	28	.....	.....	.....	.....	125	20
Keeler	64.2	110	14	64.6	112	23	61.8	112	17
Mohave	62.7	106	15	67.6	107	23	66.2	114	20
Needles	.....	.....	.....	75.7	111	35	57.3	114	26
Palm Springs	70.4	117	32	75.6	113	32	70.4	122	28
Volcano	74.6	120	25	73.1	117	22	73.6	128	24

[a] California section of the climate and crop service of the Weather Bureau, annual summary, 1903, pp. 8–9.
[b] Idem, 1904, pp. 8–9.
[c] Idem, 1905, pp. 8–9.

Rainfall, in inches, at 10 stations in California.

	Mean annual.[a]		Annual 1903.[b]	Annual 1904.[c]	Annual 1905.[d]
	Years included.	Amount.			
Bagdad	.....	.....	2.32	2.30	9.90
Barstow	.....	.....	2.65	0.80	6.40
Bishop	1884–1900	4.27	1.56	7.61	5.19
Imperial	.....	.....	0.34	.....	10.06
Indio	1878–1900	2.43	.....	.....	.....
Keeler	1884–1900	2.76	0.10	3.50	6.80
Mohave	1877–1900	4.79	1.87	2.86	6.45
Needles	1892–1900	2.79	.....	1.24	11.36
Palm Springs	1889–1900	3.53	0.70	.....	9.36
Volcano	1889–1900	1.70	0.20	1.90	6.18

[a] Monthly Weather Review, vol. 30, No. 4, April, 1902, pp. 208–209.
[b] California section of the Climate and Crop Service of the Weather Bureau, Annual Summary, 1903, pp. 16–17.
[c] Idem, 1904, pp. 16–17.
[d] Idem, 1905, pp. 16–17.

The average rainfall for six years at Bishop, Inyo County, was 3.64 inches; at Camp Cady, on Mohave River, an average of 3.08 inches for two years is recorded. Daggett, San Bernardino County, had an average of 4 inches for three years. At Yuma, Ariz., a twenty-eight year record gives an average of 3.16 inches. It is probably safe to say that the normal rainfall for the desert is between 3 and 4 inches annually, but this average is derived from annual extremes ranging from seasons of no rainfall to those having as much as 10 inches.

WATER SUPPLY.

ORIGIN.

A portion of the rainfall in this region is carried off by evaporation as soon as it falls; another portion soon sinks and joins the ground water, which permanently saturates the rocks below a certain level; still another portion finds its way directly to the streams, which carry it to sinks or lakes to be again evaporated. The moisture that has been evaporated from the surface of the Pacific to float inland as vapor and be condensed again to water the earth is the original source from which practically all of the meager supply of the desert comes, but this does not mean that each spring is dependent on the rainfall in the region immediately around it. Many of the springs of the desert are of deep origin and are not fed by local rains, and the waters that supply them fall on mountains far from the points where they issue.

RIVERS.

Only four of the streams that flow toward the Great Basin from the Sierra Nevada and Sierra Madre extend beyond the base of the mountains. The others sink at once into the sands of the desert.

The waters of Owens River, which heads in the Sierra Nevada north of Mount Whitney, have been secured in part by Los Angeles, and are to be conducted across the desert to supply that city and the surrounding region with pure mountain water. For years a part of the waters that feed this river have been utilized on the fields of stockmen and farmers along its course, but the greater portion has been wasted in Owens Lake, a soda lake that has no outlet.

Amargosa River rises in springs in the mountains northeast of Bullfrog and flows southward intermittently across the desert through Franklin Lake to Resting Springs Dry Lake. On leaving this lake it enters a canyon, about 10 miles long, between Black and Kingston mountains. From this canyon it emerges into the south end of Death Valley and turns westward to Saratoga Springs, whence it flows northwestward to the sink of Death Valley. The north end of Death Valley lies nearly due west of the head of this river, so that the depression as a whole has the form of a long and narrow U. Ordinarily there is water at only a few places along the Amargosa channel, but when a cloud-burst occurs within its drainage area it may become for a few hours a raging torrent. At Resting Springs Dry Lake the stream at such a time has been over a mile wide and several feet deep. But since 1850 the river has not been known to carry enough water to flow on the surface as far as the lowest depression of Death Valley; and in its heaviest floods it rarely extends more than 4 or 5 miles below Saratoga Springs.

The waters of the Amargosa are briny along its lower course. Where it widens out into the large playa at Resting Springs Dry Lake it leaves fields of salt as well as of borax and niter. The desert for many miles on either side of the river is dotted with spots and patches of salt. Hot springs discharge into it at a number of places.

A dry wash marks the channel of the South Amargosa, which rises in Silurian Dry Lake, at the east end of the Avawatz Mountains, and runs northward to Salt Spring. Here it turns northwestward and joins the main river in South Death Valley, a few miles east of Saratoga Springs.

Mohave River rises in the San Bernardino Mountains and flows northward. The Santa Fe Railway follows approximately its course to Daggett. There the river turns northeastward and is followed by the line of the San Pedro, Los Angeles and Salt Lake Railroad until it passes through the canyon at the Caves. East of this canyon it sinks finally in Soda Lake. The divide between Silver Lake, in the Mohave drainage basin, and Silurian Dry Lake, the source of the South Fork of the Amargosa, is but 30 feet high, and consists only of sand. Thus the two river systems are separated by a very low and frail barrier.

Soda Lake, into which the Mohave finally disappears, is known also as Mohave Sink. During the wet season the waters of this lake range from a solution approaching saturation to one containing but 282 parts of solids in 100,000. In the dry season the greater part of the depression is covered with a heavy mineral crust, rich in various salts.

New River rises in Mexico, on the delta of Colorado River, whose overflow waters feed it, and flows northward into the Salton Sink. Other channels across the Colorado Desert have a similar origin and direction. One of these is Salton or Alamo River, which is almost equal in importance to New River. Salton Sink is normally a salt-incrusted depression, whose lowest point is 273½ feet below sea level. For years it was the source of supply of salt for the New Liverpool Salt Company, but it now contains a lake, caused by diversion of the waters of the Colorado to it through the New and Salton channels.

SPRINGS.

In the higher mountains of the desert there are many "hillside" springs, whose source is the rainfall of the immediate neighborhood, but many of these springs are not permanent and are not to be depended on by travelers.

The greater permanent springs are deep seated and many of them probably lie along fault lines. Among the springs of this type whose flow seems to be too strong to be accounted for by local rainfall are those at Pahrump, Manse, and Saratoga.

Probably because of the depth to which the waters of these springs descend during their long subterranean passage, and the heat and pressure to which they are subject, they become active solvents of mineral matter, and issue along the fractures as heated springs, carrying a large percentage of solids in solution.

The waters of many of the desert springs presumably possess valuable therapeutic qualities, and complete quantitative analyses of them are warranted. Other springs furnish only ordinarily wholesome waters, that have acquired a local reputation for the treatment of disease. "Poison springs," said to contain arsenic, have been reported from many parts of the desert. The writer has examined the waters of several of these, but has failed to find any arsenic or similar poison, though he has found large quantities of sulphate of soda (Glaubers salt) and some sulphate of magnesia (Epsom salts). Salt Spring, in South Death Valley, is of this character, and prospectors are known to have perished there, so that the spring is called "poison" by many, but it contains only sodium and magnesium salts, and no arsenic or copper.

The intense heat of the summer, the exhausted condition of the famished prospector, and the abundance of these harmful salts in the waters are sufficient explanation of the deaths that have occurred. Such waters are dangerous to a hearty, healthy man who uses them with the greatest moderation, and they may be quickly fatal to the thirst-tormented sufferer who drinks them without restraint.

FINDING WATER.

CAMPING PLACES.

Many of the springs and wells in the desert may be located without special description, particularly those that are near a main route of travel. Prospectors and mine owners usually enter the field each fall to do assessment work on their mining claims. On these journeys they follow well-established roads or trails and so plan the trip as to stop at the springs where they will find the best water. As fuel is scarce, the ground in the immediate vicinity of the springs is usually so thoroughly cleared of brush as to be practically bare. Near these permanent and well-known springs, piles of tin cans and other débris left by campers are always to be seen. Where the location of such springs is sufficiently obvious, no detailed description of the surroundings is given in the following pages.

The traveler who is unacquainted with the route over which he is journeying should stop at places where the ground has been cleared of brush and where there is other ample evidence of the presence of many visitors, and satisfy himself as to the nature of the camp. It may be a "dry camp," such as are made on long stretches between springs, or there may be a spring or well in the vicinity, which is covered over to keep out animals, and is hidden by drifting sand. Experienced men will have no difficulty in quickly determining the nature of the camp. An inexperienced traveler should not enter the desert alone. If he can not find an experienced companion, he should proceed with the greatest caution, gathering all possible information about his route in advance, keeping himself abundantly supplied with water and food, and never leaving one water station without a definite idea as to the location of the next.

A traveler can rarely see exactly where water is to be found, except by going over the camp ground and looking carefully for wells. Many of the wells are mere shafts, 20 to 40 feet deep, rectangular in shape and covered with a few boards, which may in turn be buried by drifting sand. Only a few wells are equipped with a windlass or pump. These conveniences, even if originally supplied, quickly disappear as fuel for some traveler in need on a cold winter night. He uses them to maintain his camp fire, justifying himself in the belief that self-preservation is the first law.

Prospectors and mine owners often wish to find water in new districts, away from the main lines of travel. In their search for it they must be guided by geologic and topographic conditions and by the vegetation, which is often a useful guide.

MOUNTAIN SPRINGS AND TANKS.

As a rule the water found at high elevations comes from rocks free from alkalies and is pure and sweet. In hunting for these higher springs one must go up to the bare, rocky gulches, above the loose material into which the rain waters sink so readily and are lost. The mountain springs are small and the majority of them disappear during the drier periods, but for a short time after a storm they may be abundant and furnish strong flows.

In the lava or granite ranges water from the winter rains often collects in rock bowls. Where these are in the shade and are protected from the wind, water may remain in them for months after a storm. Such natural reservoirs are known as "tanks." After rains they may be valuable sources of supply for prospectors, but after a series of long, dry seasons they are not to be depended on. Some of these tanks are of large capacity and are very valuable to mining camps. They are so rare, however, that travelers can not expect to find them in an emergency without knowing their whereabouts or their character.

DRY LAKES.

In the vicinity of the dry lakes—the sinks of the desert—water may generally be found by digging or boring wells. These playas are the lowest points in local drainage basins. When the rains in such a drainage basin are heavy enough to induce a surface flow to the depression the waters collect there to sink gradually or to be evaporated. These sinks have no surface outlet, and some of them are rock-floored and have no underground outlet. All of the surplus water of the local watershed is, therefore, impounded in them. Although it may not accumulate at the surface, its quantity is usually sufficient so that comparatively shallow digging will reveal its presence. The supply in such a basin does not depend entirely on the amount of water that reaches the depression over the surface. An important percentage of the lighter rains is absorbed by the débris along the flanks of the desert ranges and percolates slowly through the sand and gravel to the playa. A part of the floods resulting from the rare cloud-bursts and heavier storms is also absorbed in the same way and seeks the lowest point in the basin by passage underground through the pores of the gravel.

These accumulated waters may usually be developed by the mining community or by the prospector who wishes to establish a permanent camp. The favorable place for undertaking such development, however, is not in the mud flat—the playa itself—but around its borders. All flowing and percolating waters dissolve alkalies from the rocks, sands, and gravels over and through which they flow. At the point where the waters are evaporated these salts are left behind as saline deposits. As the bottoms of these sinks are merely great evaporating pans, accumulated surface waters and rising subterranean waters both passing into the air there, they are almost invariably alkaline, and usually the alkalies extend to considerable depths. The waters in the center of the sink are impregnated with these salts and are generally not usable. But as the ground waters always percolate toward the lowest point, the waters found about the borders and at short distances back from the playa are relatively pure, since they have not yet entered the highly alkaline area. To reach the water plane at these points about the borders of the sink it may be necessary to penetrate to a greater depth than would be required nearer its center, but usually this is the only way in which potable waters can be developed at such places.

GEOLOGIC HINTS.

As already stated, pure water may be found in springs, pools, and tanks in the areas of granite, lava, or other compact rock. The favorable time to find such water is immediately after the rains or snows of winter. Many of these springs and pools are short-lived, but they furnish water of the best quality, and even immediately after rains no water can be found in the desert valleys, for their sands and gravels absorb the rain as fast as it falls.

Many inquiries are made as to the value of tunneling along a crevice from which a slight seepage escapes, in order to develop a greater supply. Of course it is well to clean out the opening from which the water comes, so that it may flow freely, and to go deep enough to see that none escapes by side channels, but more extensive development work is usually disappointing. If the water of the spring is derived from a saturated body of gravel, tunneling will result in a temporary increase of flow, as the drainage of the gravel body is improved. But in rock even a temporary increase is often not procured, so that there is no return for the expense. A bed-rock tunnel to develop water in arid regions is in the majority of cases a failure. The experience of miners in developing their prospects shows that most of the tunnels that are run into the desert mountains are dry, at least until they have been driven a great distance, and that they develop water only under exceptional conditions.

Next to unconsolidated deposits, the rocks that present the conditions most favorable for direct absorption are uncemented sandstones and certain porous limestones. In granites, slates, and other compact rocks the direct absorption is very slight.

Sandstone is on the whole the best water-bearer among the solid rocks. Under the most favorable conditions the rock is saturated throughout its extent below the regular ground-water level, and water is yielded wherever the sandstone is struck by the drill below this limit.

Conglomerates sometimes furnish water in considerable quantity, although as a rule their absorptive capacity is not so great as that of sandstones, and they are much less commonly encountered.

Sands and gravels are very porous, the free space between the grains occupying from 30 to 40 per cent of the total volume. A mass of such materials is saturated below the permanent water level, and when penetrated by wells yields copious supplies. The waters are generally of good quality, but are at some places mineralized, the mineral matter being derived from the more soluble fragments and particles of the deposits.

Clay is very impervious to water, and usually contains little or none that can be utilized as a source of supply. The water that is frequently reported in clays usually comes from layers that are more or less sandy. Some sands which approach clay in fineness, and which are at times mistaken for it, yield considerable amounts of water. Clay is of the greatest importance, however, in connection with water supply, not as a direct water-bearer, but as a confining layer to porous sands, from which it prevents water from escaping.

Shale, like clay, is a poor medium for the storage and transmission of water, but may yield it from bedding, joint, or cleavage planes. Its most important use is as a confining mass to prevent the escape of water from porous layers which may be interbedded with it.

The water derived from limestones occurs mainly in open channels dissolved in the rock by the water itself. Probably the water originally followed joint or bedding planes, which were gradually enlarged by solution into the caverns now found. The occurrence of caverns and passages within limestone is very irregular and their location can not be predicted. Wells that are sunk in limestone only a few feet apart may show very different results, for a difference of a foot or two in the position of the boring may mean the missing of a particular channel.

Granites and gneisses are dense and possess small pore spaces, and hence hold very little water. Schists, however, may carry water along the foliation planes, but give it up very slowly, and are not, therefore, important sources of supply. The largest supplies from

schists are obtained along joints. These joints are most common near the surface, diminishing in number and in definiteness as depth increases.

VEGETATION AS A GUIDE.

The flora of the usual thoroughly arid sections of the desert varies but little in character. Tracts for miles in extent are covered by an almost uniform vegetation consisting of but a few species that show only here and there slight variations, due to the local differences in the physical or chemical nature of the soil. The presence of water, however, produces marked changes, hence the character of the vegetation is an excellent indication of the possibility of obtaining water near the surface.

At scattered points in the broader valleys or in the more restricted gulches are numbers of dead sycamores or cottonwoods. Their presence usually indicates the lowering of the water table in that region, and it is not likely that a supply will be found within 20 feet of the surface.

The dry lakes are nearly all absolutely free from vegetation. This lack is probably due to the intermittent flooding of the surface, to the frequently renewed deposits of mud, and to the excess of alkali present.

Although mesquite (*Prosopis juliflora*) grows luxuriantly where water is abundant, its presence is not a good guide to water, for its growth may depend on either the proximity of the ground water or the periodical flooding of a small area. Where its growth is due to ground water it furnishes no suggestion as to the depth to the water. It may lie within a few feet of the surface or it may be 50 feet below. Where its life is sustained, as in restricted gulches, by occasional floods, obviously water will not be found by digging during the drier periods.

Tules, or bullrushes, always indicate water at or very near the surface, and generally water of good quality.

Lowland purslane (*Suaeda portulacastrum*) is a plant that grows on moist alkaline soils. It indicates water, but usually water of poor quality.

Wild heliotrope (*Heliotropium curassavicum*), sometimes called "Chinese pusley," is one of the rarer plants. It grows only in moist soil, but since it has strong alkali-resisting powers the water near it may be brackish.

Arrowweed (*Pluchea sericea*) is another moisture-loving plant found in the desert. Where it grows to a height of 6 or 8 feet in a dense tangle it is reasonably certain that the ground water lies within 20 feet of the surface and that its quality is at least fair.

Salt grass (*Distichlis spicata*) indicates water very near the surface, but this plant prefers alkaline areas, although not confined to them; hence the water indicated by it may be very brackish.

Creosote (*Larrea mexicana*) and the numerous shrubs (*Sarcobatus*, *Grayia*, etc.) of the greasewood group, which are widely distributed over the deserts, grow in the driest of soils, and although some of them, like creosote, flourish better with a moderate amount of water their presence may generally be taken as an unfavorable indication.

HINTS ON DESERT TRAVELING.

TEAMS, HAY, AND GRAIN.

Where teams are used animals accustomed to the desert should be procured, if possible, for horses or mules that are unused to desert conditions fret on the sandy roads and rapidly weaken from drinking the saline waters. They are also in danger of pneumonia from the cold of the winter nights and the wide extremes of temperature. During winter journeys blankets should be provided to protect the animals at night.

Travel in the desert far from the railroads and from food supplies is, of course, more expensive than in other regions. A party leaving a supply station to go 100 miles or more into an uninhabited part of the desert must take along everything needed, even to the most minute detail. This means that if the trip is to last for two weeks enough hay and grain for each animal and enough provisions to last each man that length of time must be taken. For four horses, drawing a wagon that carries four persons and their bedding, provisions, and tools, another team of four horses must also be taken to haul sufficient hay and grain to feed the eight horses for two weeks. There are but few places in the desert, away from the railroads, where grain or hay of any kind can be procured. As the teams are rarely able to travel faster than a walk, heavy horses that are good walkers should be selected. The tires should be as wide as can be procured. Desirable widths of tires for freight wagons are 6 to 9 inches; for light wagons 3 inches.

A good feed trough may be made as follows: Take two pieces of surfaced 2 by 4 lumber, about 4 feet long. Cross them in the form of an X and fasten them together with a bolt, so that they can be folded for packing in the wagon. Near the top of each arm of the X fasten a heavy hook to which a canvas may be attached. This X should be fastened to the end of the wagon tongue, and a piece of canvas properly shaped should be stretched from it to the front wheels of the wagon to form a broad trough. The tops of the crossbars should be fastened together with rope to keep them from spread-

ing: the bottoms should rest on the ground. Both hay and grain should be fed from such a trough, which saves waste and provides a more healthful mode of feeding than eating out of the dirt. Nose bags may be carried for feeding grain during the short stops at noon. For packing trips experienced prospectors select burros on account of their endurance of heat and thirst, their foraging abilities, and the slight amount of care they require. They are slow and too light to carry heavy packs, so that on expeditions where speed is essential, or heavy freight is to be moved and feed is available, horses or mules are to be preferred.

TOOLS.

Travelers will often find springs choked by débris washed in by rain storms or contaminated by the bodies of desert animals that have fallen in and drowned. It is therefore necessary to provide a pick, shovel, bucket, and rope for cleaning the wells.

CLOTHING, BEDDING, ETC.

At all times except in midsummer—when the desert should be avoided—the traveler must be provided with clothing suitable for both extreme heat and extreme cold. His route over a part of the journey may extend through heated valleys that lie near sea level, or he may have to camp in the mountains, at elevations of 3,000 to 6,000 feet, where the temperature may fall nearly to the freezing point before morning. For protection during the early morning hours he must therefore have warm, heavy blankets and a heavy overcoat or its equivalent. Many cases of pneumonia and "mountain fever" have been caused by extremes of temperature for which no adequate provision had been made. In winter the temperature in this region may reach 85° or 95° during the day and fall to the freezing point before midnight. The traveler should be provided with a canvas sheet that is long enough to lay under his bedding and fold back over it, as well as to cover his head in case of sand storms. Folding cots and air mattresses are luxuries that may be taken if the financial resources of the party are sufficient to provide such supplies and ample means of transportation.

The outer clothing should be of a color that will reflect as much heat as possible—that is, white, gray, or yellow—and the underclothing should be of wool. The hat should have a wide brim and be thick enough to exclude all rays of the sun. The proper headgear is a broad-brimmed gray felt, or, for summer wear, a big opaque helmet of white or khaki color, the bigger the better. The hair should not be cut very short, as it is a natural means of protection.

Travelers with their own outfits and a minimum means of transportation will find that they must walk much of the time, for teams with

heavy loads can only crawl through the sands at the rate of 2 to 3 miles an hour. Sand and sharp flints will wear out the soles of boots and shoes very rapidly. Hence stout hobnailed footwear should be worn.

PROVISIONS.

In the more important mining camps and at the principal railroad points there are eating houses, where the traveler who follows railway and stage lines may procure food; but in actual desert travel in regions far away from these few local points full provision must be made at the outset for the entire period to be occupied in the journey. The staples of camp supplies, such as flour, sugar, tea, coffee, rice, bacon, beans, breakfast foods, etc., are well known, but means and personal taste will to a great extent dictate the further choice. The monuments of tin cans at the various camping places testify to the popularity of the various foods preserved in tin. The better brands of canned meats, fruits, and vegetables are excellent and will form an important and most refreshing part of the menu of the more elaborately equipped parties. Where long journeys are planned and transportation facilities are limited, canned goods must be eliminated, largely because of their weight, and dried foods substituted. Soups, meats, potatoes, and other vegetables, as well as fruits, may be had in dried form, and a considerable range of choice is possible. Condensed cream is recommended, even where it is necessary to economize in weight, for it not only makes possible a much wider range in cooking, but it counteracts in great measure the irritation produced in the digestive tract by the alkaline desert waters, and is therefore especially desirable.

WATER.

Owing to the intense heat of the desert there is a rapid and abundant growth of minute forms of animal and vegetable life in waters that are not too saline. All water should therefore be boiled before drinking. Filters form a part of the more elaborate outfits. There are now on the market several small, compact filters from which the traveler may select such as he may think desirable. It is not practicable to distill water except for mining camps or for large parties.

It is advisable to drink heartily in the morning and at night and as little as possible during the day. The practice of drinking water in excess of the amount necessary to relieve thirst may easily become a habit and should be avoided. At best it places an unnecessary tax on the system, and, when alkaline waters are used, may easily result in illness that could have been prevented by the exercise of greater foresight and self-control. It has been recommended that raw oatmeal be placed in the canteens, and some travelers even add to this a

small quantity of chocolate and sugar. When the water becomes tepid, additions of this kind make it more palatable to some, and there is less temptation to drink too much. It is well, also, during periods of extreme heat to wrap a wet cloth around the wrists and to put a water-soaked handkerchief in the hat. These are old-fashioned but effective devices. Each person in a party should be supplied with a large canteen, and extra ones should be taken along in the wagons to provide for leaks and accidents. An ample supply of water barrels and kegs should also be carried for use at dry camps and during prospecting trips, the number depending on the amount of stock taken and the route followed.

FUEL.

Fuel is scarce in the desert, especially in the vicinity of the better-known springs, where it has been entirely cleared away. The traveler therefore usually finds it necessary to begin gathering brush and mesquite roots long before he reaches a spring, so as to provide fuel for cooking. Camp fires are luxuries that can be indulged in only among heavy mesquite and cottonwood timber, or off the beaten lines of travel.

GETTING LOST.

One unacquainted with the desert should accustom himself to its clear air and the resulting exaggerated detail, which makes distant objects look near. No walks without water or provisions to what appears to be a near-by hill should be undertaken without definite knowledge of its distance. Landmarks should be studied, so that they will be recognized from any point of view, that they may be known when they are reached again. Before he begins a journey that does not follow a beaten and unmistakable track, the traveler should determine his general direction by compass or map or inquiry, and should adhere to that direction. The inexperienced traveler often gets at once into a panic on losing his way, and wastes his remaining energy in frantic rushes in one direction and another. This tendency to become panic-stricken should be controlled, if possible. Sit down, get out your map and compass—if you are provided with them, as you should be—and study the situation carefully before acting. At least, rest a little and think it over. If it is hot and you are far from camp, get your head into the shade of a bush or rock, and wait till night. Thirst will be less intolerable then and endurance greater. If you have camp companions who are likely to look for you, start a signal fire by night or a smoke by day from some little eminence, and then stay by it until help comes. If you must depend on your own exertions, think carefully over all the possibilities and adopt a plan of action and adhere to it. Remember the proneness of the lost person to exaggerate the distance he has trav-

eled. It is well to count paces and to remember that about 2,000 make a mile. You will thus have a good check on the distance that you go, and at the same time will keep your mind occupied. Keep your direction true by traveling toward or from some selected landmark, or by the sun during the day or a star at night, or by keeping with or against or in some fixed direction in relation to the wind. If you think these things out and have studied the country beforehand, so that you know the relation of a road, or a ranch, or a spring, or a river to a given landmark or to the points of the compass, you should have no difficulty in finding your way again. With some persons, however, the faculty of getting lost amounts to genius. They are able to accomplish it wherever they are. The only suitable advice for them is to keep out of the desert. There are safer places in which to exercise their talent. Still others have a geographic instinct and a power of geographic observation which defies time and place. They can not be lost anywhere. For such these lines are not written.

MAIN ROUTES OF TRAVEL.

STARTING POINTS.

Most of the main routes of travel in the desert are by no means straight, but make long detours, their courses having been determined either by the location of watering places or by the desire to avoid crossing desert ranges. A long way round to a given place on the desert may be not only easier but safer than a more direct line. Nearly all the travel into these regions starts from the Santa Fe, Salt Lake, or Southern Pacific Railroad, and the descriptions that follow are given accordingly. In returning from his destination the traveler has only to retrace his steps.

FRÉMONT'S TRAIL.

Gen. J. C. Frémont, in April, 1844, entered the Mohave Desert at Cameron Salt Lake, about 22 miles northwest of the modern town of Mohave. From that point he followed the east base of the Sierra southward to what is now known as Water station. Thence his course was southeastward past the Desert Buttes, until he reached Mohave River at "Point of Rocks," near what is now known as Cottonwood station, on the Santa Fe. There he turned down the Mohave to the point where the old Spanish trail left it, about 10 miles east of Otis. From that point he followed the old Spanish trail northeastward to Tomaso Springs; thence northward past the east edge of the Avawatz Mountains to Salt Spring and the canyon of the Amargosa, which he followed up to China Ranch Springs, on Willow Creek. From China Ranch Springs he journeyed to Resting

Springs, where his course was altered to the northeast toward Vegas Warm Springs, in Nevada. This route between Cottonwood, Otis, and Resting Springs is still used.

OLD SPANISH TRAIL.

When California belonged to Mexico, caravans made regular trips over a well-defined trail that connected Los Angeles with points in Utah. This trail crossed the mountains north of San Bernardino by the Cajon Pass, and followed Mohave River down to a point east of the Calico Mountains. There the trail forked, one branch leading across the east edge of Alvord Mountain to Bitter Spring and Tomaso Springs and thence northward along the east edge of the Avawatz Mountains to Salt Spring, the other branch continuing down the Mohave to its sink, then crossing Soda Lake and Silver Dry Lake and joining the first branch in the pass between the Avawatz and Shadow mountains. From Salt Spring the trail led northward through the canyon of the Amargosa to Resting Springs, then eastward by way of Stump and Crystal Springs to Las Vegas Warm Springs, where it turned northeastward to Virgin River. This route was used later as the mail route from Los Angeles to Salt Lake City, mail being carried over it once a month for many years.

These roads are still used by travelers from Daggett to Shadow and Silurian mountains or to Soda Lake.

MOHAVE-KEELER ROUTE.

Those who desire to reach points in the western part of Inyo County will find the stage road from Mohave to Keeler the best route. It is an old-established, easily followed road, and watering places and road houses are distributed along it. It follows close to the foot of the Sierra Nevada from Mohave station on the Santa Fe and Southern Pacific railroads, northward to Water station, whence it passes through Redrock Canyon, at the west end of the El Paso Range, and on northward to Freeman, Indian Wells, Little Lake, Haiwee, and Olancha. From Olancha one road skirts the west side of Owens Lake to Lone Pine and Independence, the county seat of Inyo County. From this route, as shown by the map (Pl. I), other roads lead eastward to most of the mining districts.

DEATH VALLEY ROUTES.

There are three main routes by which Death Valley may be reached from the south. One starts from Johannesburg, another from Daggett, and a third from Barnwell.

The Johannesburg route runs by way of Blackwater and Granite Wells. A heavily laden team can leave Johannesburg late in the

morning and reach either of these camping places in the evening. A dry camp should be made between Granite Wells and Leach's Spring, the next watering place, as the distance is 45 miles, and pulling is hard over the last 6 miles on account of deep sand and heavy grades. From Leach's Spring the route leads to Owl Springs, Saratoga Springs, the China ranch, and thence to Resting Springs. At Resting Springs directions should be obtained for going to the head of Furnace Creek, whence the route follows down Furnace Creek to the Borax Works at Coleman, in Death Valley.

The Daggett route is a favorite with many. This road runs from Daggett to Otis, thence east of the Calico Mountains to Coyote Well, and across the dry lake to Langford Well and Garlic Spring. From this spring the road passes to the east of the Granite Mountains and climbs the Avawatz Mountains to Cave Springs. From Cave Springs it leads to Saratoga Springs and thence to Resting Springs.

The Barnwell route was for a number of years traveled by a daily stage running from Barnwell, Cal., to Manse, Nev., but the stage has been abandoned since the construction of the Salt Lake Railroad. This route is still preferred by some travelers, who obtain their supplies at Barnwell or at Ivanpah. From Ivanpah the road extends across the dry lake to the north, thence through the State Line Pass to Mesquite Dry Lake and Sandy; from Sandy northwestward to Stump Spring and Manse; thence to Pahrump and Johnnie and Miller Well No. 2, where it joins the stage road from Las Vegas to Bullfrog.

Outfits may also start from Roach or Jean, Nev., and go westward to Sandy. At Pahrump, on this line, roads branch to the Fairbanks ranch at Ash Meadows, but it is advisable to go by way of Johnnie to Miller Well No. 2, and thence to the Fairbanks ranch, where there are springs. A number of recent changes and improvements in the roads give good routes to the head of Death Valley. Travelers can obtain all information regarding these changes at Pahrump and at the Fairbanks ranch.

BULLFROG ROUTES.

Three main routes lead to the Bullfrog mining district, from Las Vegas, Ivanpah, and Goldfield. Travelers over the Death Valley routes can connect with the Bullfrog roads by driving from Resting Springs to Manse, Pahrump, or the Fairbanks ranch.

A wagon road runs from Las Vegas, Nev., northwestward by way of Tule Spring to Indian Springs, thence westward to Miller Wells Nos. 2 and 1, and northward to Beatty, Rhyolite, and Bullfrog. This route is 130 miles long.

Ivanpah is the terminus of a branch of the Santa Fe Railway which leaves the main line at Goffs (Blake post-office), Cal. From

Ivanpah a stage line runs northward by way of Sandy, Manse, and Pahrump to Miller Well No. 2, where it connects with the Las Vegas road. This route is highly regarded, as the water supply is excellent, and hay and grain can be obtained at the four stations mentioned. Bullfrog is about 135 miles in air line northwest from Ivanpah.

A wagon road runs from Goldfield to Bullfrog by way of Cuprite and Bonnie Claire station, which lies on the west side of Sarcobatus Flat. From Bonnie Claire station the stage follows the east foot of the Grapevine Mountains, by way of the Tonopah Well, Seattle Well, and the old town of Bullfrog, entering the new town of Bullfrog from the west. This route is about 80 miles long.

SEARCHLIGHT ROUTE.

The Searchlight mining district is best reached by a branch of the Santa Fe that leaves the main line at Barnwell.

NEEDLES-PARKER ROUTE.

The southeastern portion of the Mohave Desert is best reached by the road running from Needles southward to Parker. Two wells, dug by the county, and known as the "old" and the "new" West wells, furnish water to the traveler. There are no settlements on the route. The completion of the Santa Fe line now under construction from Bengal to Parker will give easier access to this district.

AMBOY-DALE ROUTE.

A stage line connects Amboy, on the Santa Fe Railway with the Dale mining region to the south. Water can be had at the stage station along the line.

MECCA-DALE ROUTE.

An excellent road starts from Mecca, in the Coachella Valley, on the Southern Pacific Railroad, and runs northeastward to Shaver well, thence along the west flank of Eagle Mountains and the east side of Pinto Mountain to Dale. This road is well supplied with good water, and is the main route into this region from the south.

VICTORVILLE ROUTES.

Victorville station, on the Santa Fe Railway, is the starting place for points in the southern portion of the Mohave Desert east of the Santa Fe. A county road crosses Mohave River here by a good bridge, and branches of this road run along the east side of the river to the various mining camps. The main county road runs eastward by way of Dead Man's Point, at the south end of Granite Mountain, to Box S ranch. At this ranch the road forks, a northern branch lead-

ing eastward by way of Old Woman Springs, Mean's Well, and Surprise Spring to Twenty-nine Palms Springs and Dale. The southern road goes by way of Box S Springs, Cushenbury Springs, and the Rose Mine to Twenty-nine Palms Springs. This road crosses the northern edge of the San Bernardino Range, rises to high altitudes, and has heavy grades. The northern route is the better.

BANNING-DALE ROUTE.

From Banning a wagon road runs by way of Warren's Ranch, Warren's Well, Coyote Holes, and Twenty-nine Palms Springs to Dale.

IRRIGATING AND ARTESIAN WATERS.

IRRIGATED AREAS.

The arid region shown on Plate I is bounded on the east, west, and south, respectively, by Colorado River, the Sierra Nevada, and the Sierre Madre. The only places in this wide area where irrigation is generally practiced are found along the east base of the Sierra Nevada in Inyo County; in the Elizabeth Lake, Palmdale, and Little Rock districts north of the Sierra Madre in Los Angeles County; in a few small tracts along Mohave River in San Bernardino County; in the Imperial district in Imperial County; the Indio section in Riverside County, and at a few points along Colorado River. In the desert proper the patches reclaimed by irrigation vary in size from 4 or 5 acres to 160 acres, and are isolated and exceptional, serving only to emphasize the barrenness of the rest of the region. These oases are all watered from springs and will be mentioned in the detailed descriptions.

ARTESIAN WATERS.

Certain areas give evidence of having a supply of artesian water as yet undeveloped or but partly developed, but their exact limits and the amount of water available in them can be ascertained only by special study. The writer desires to call attention to the fact that they exist and that some of them are worthy of detailed investigation.

Artesian zones border some of the larger playas or dry lakes which have a relatively abundant water supply. Near the southern and western limits of the Mohave Desert there are several such basins whose waters are supplied by the run-off from the Sierra Madre and Sierra Nevada. An important basin of this type exists also in the northwest arm of the Colorado Desert, about Indio, where several thousand acres of land are under irrigation by the use of artesian waters.

In addition to water in sufficient quantity to give the necessary head, certain mechanical conditions, such as a proper alternation of pervious and impervious strata, are necessary to establish and maintain artesian conditions. Furthermore, such basins in the desert are usually readily exhausted, because the amount of water available to replenish that drawn out for irrigation or other uses is small. In planning municipalities, large mining camps, or extensive irrigation from such waters, care must be taken that their quantity is not overestimated.

Artesian waters have been obtained near Haiwee, in Inyo County, between the Sierra and the Coso mountains; at the head of the Salt Wells Valley between the El Paso Range and the Sierra; and west of Kane Dry Lake in Kern County. Another belt in which artesian waters have been developed lies along the north edge of the Sierra Madre in Los Angeles County, in the vicinity of Lancaster. Other artesian belts lie east of the latter zone along the north front of the San Bernardino Range, in the neighborhod of Victorville and farther east in what is known locally as the Lucerne Valley district. The principal wells drilled in this valley are mentioned under the heading "Box S ranch."

Artesian waters have been tapped in the northeast corner of Riverside County, in T. 2 S., R. 19 E., San Bernardino meridian. They have been found also on the northeast edge of the basin, of which Rodriguez Dry Lake is the sink, at the Flowing Wells.

DESCRIPTIONS OF SPRINGS.[a]

SYMBOLS USED.

Springs, wells, flowing wells, and pumping plants are represented on the map by appropriate symbols, and those described in the text are given numbers; others, whose locations are known but for which no descriptions are available, are indicated by symbols only.

In the arrangement of the descriptive matter the plan adopted is to divide the map into rectangles, each covering an area of approximately four townships. These rectangles are identified by letters and numbers along the margins of the map. The numbers and the corresponding descriptions in the text begin at the northwest corner of the map and follow the first row of rectangles eastward to the Nevada line. They then begin in the next row of rectangles to the south and follow it eastward. When all of the descriptions available for California have been given in this order, the same plan is adopted for that part of Nevada described, but the California and Nevada numbering is continuous. Locations can not be given by land lines, because there are many unsurveyed areas in the desert, and even

[a] Arranged by map numbers. References to positions on the map, in parentheses, follow the headings.

where surveys have been made they are old, much of the work having been done between 1852 and 1860, and corners are usually missing. Both on this account and because of the very general way in which many of the springs have been located it is not possible to give the section within which they are found.

CALIFORNIA.

1. *Oasis, Mono County* (A-2).—Oasis is a settlement near the California-Nevada line west of the Palmetto Range. It is about 30 miles northeast of Alvord station, on the Southern Pacific Railroad, and about 15 miles northeast of Deep Springs (No. 2). Oasis serves as a general outfitting point for prospectors in the Palmetto Range. It is well supplied with water from both springs and wells.

2. *Deep Springs, Inyo County* (A-2).—At the south end of Deep Springs Valley there are large flowing springs that have been known since the earliest settlement of the north end of Inyo County, and that have given a name to the settlement and to the valley. They are 13 miles east of Poleta station and about 18 miles northeast of Alvord station, on the Southern Pacific Railroad. They furnish sufficient water to irrigate about 600 acres. The settlement is the principal stopping place between Alvord and Oasis.

3. *Sand Springs, Inyo County* (B-3).—Sand Springs are about 19 miles west of south, in an air line, from Lida, Nev., on the west side of the north end of Grapevine Mountains. They are in Termination Valley near its north end, about 16 miles northwest from Stainінger's ranch (No. 5). The water is good, and the site of the springs is marked by the débris left by many campers.

4. *Grapevine Springs, Inyo County* (B-3).—This is a group of springs on the bench above the floor of Death Valley, about 3 miles by trail due west of Stainінger's ranch. There is plenty of water.

5. *Stainінger's ranch, or Grapevine ranch, Inyo County* (B-4).—This ranch is in Grapevine Canyon, which drains into Death Valley, about 22 miles southwest from Bonnie Claire station, on the Las Vegas and Tonopah Railroad. It is about 11½ miles, air line, northwest of Grapevine Peak. There is an unlimited supply of good water.

6. *Barrel Springs, Inyo County* (C-1).—There are springs of excellent water in Mazourka Canyon in the Inyo Mountains, about 10 miles northeast of Independence and 6 miles north of Citrus station, on the Southern Pacific Railroad.

7. *Cold Springs, Inyo County* (C-3).—There are two groups of springs near together in the northeast portion of T. 13 S., R. 39 E., about 10 miles northeast of the Saline Valley borax works (No. 13). The springs of one group yield hot water, those of the other cold water. The hot springs lie farther south than the cold. The water

from the springs of both groups is of good quality, and there is a sufficient quantity, if developed and conserved, to irrigate several acres.

8. *Rest Spring and Burro Spring, Inyo County* (C-3).—Rest Spring is in a shallow gulch at the head of a canyon draining southward and westward into Butte Valley. It is one-half mile west of the summit of the Panamint Range and 15 miles north of Goldbelt Spring (No. 15), to which there is a plain trail. It is 6½ miles south of Tin Mountain, the northernmost peak of the range. The flow is about 3 barrels of water daily. A trail running due north leads to Burro Spring, 1½ miles distant. This spring is in a shallow gulch at the head of a canyon draining southward and eastward into Death Valley, one-fourth of a mile east of the divide. This spring also yields about 3 barrels of good water per day.

9. *Mesquite Spring, Inyo County* (C-4).—This spring is in the east bank of the wash in Death Valley, one-half mile from the bottom. It is 6 miles southwest of Stauinger's ranch, 19 miles southeast of Sand Springs, and 11 miles northwest of the locality known as Lost Wagons. There are other springs in the desert portion of California and Nevada that are also known as "Mesquite" springs.

10. *Indian Springs, Inyo County* (C-4).—Like "Mesquite," the name "Indian" is applied to several desert springs. Those here referred to are near the northeast end of the great Panamint Range and near the south end and west side of Termination Valley on an old and little-used trail that runs southward from Lida, Nev., by way of Sand Springs to the north end of Death Valley. They are marked by remains of Indian tepees. There are said to be other springs in this vicinity, but their location is unknown except to local prospectors.

11. *Tule Spring, Inyo County* (C-5).—This spring is about 3 miles south of west, air line, from Willow Spring (No. 12) and 12 miles southwest of Bullfrog, Nev. It is on the north side of the east branch of a canyon at the foot of a cliff, 1¾ miles southeast of the high, sharp, rocky Thimble Peak. It is about 500 yards east of the trail from Bullfrog to Surveyors' Well (No. 18) by way of Willow Spring (No. 12). There is a very small quantity of excellent water. There is another Tule Spring to the southeast, near Tecopa.

12. *Willow Spring, Inyo County* (C-5).—This spring is on the east slope of the Grapevine Range, 9 miles southwest of Bullfrog, Nev., and 3 miles north of the Boundary Canyon road at the pass. The flow is 10 barrels of good water daily. There are at least 8 watering places in the desert region with which this paper deals that are known as Willow Spring or Willow Springs; so this is by no means a determinate name.

13. *Saline Valley Well, Inyo County* (D-2).—Twenty years ago Conn & Trudo manufactured borax on an old dry lake in Saline Valley, and dug a well near the works that furnished a good supply of water of fair quality. The well is still used by prospectors on their way to the copper regions on the eastern side of Saline Valley.

14. *Bird Spring, Inyo County* (D-3).—There is a spring of pure water on the trail from Keeler to North Death Valley near the mouth of a canyon on the east side of the Pinto Mountains.

15. *Goldbelt Spring, Inyo County* (D-4).—Goldbelt Spring is near the head of a western branch of Cottonwood Canyon, known as Marble Canyon. It is 8 miles by trail northwest of the head of Cottonwood Creek, 4 miles northeast of the crest of the Panamint Range, and nearly 25 miles southwest of Surveyor's Well (No. 18) in Death Valley. The spring, which is surrounded by bushes, is on the south bank of the canyon, about 100 feet above the bottom of the wash. It flows about 20 barrels per day.

Two miles east of Goldbelt Spring, and down the canyon from it, is a small spring in a clay bank on the south side of the wash. It yields perhaps 3 barrels per day.

16. *Well, Inyo County* (D-4).—This well is 7 miles southwest of Surveyor's Well, on the southwest edge of Mesquite Flat, south of the trail from Surveyor's Well to Cottonwood Canyon. The trail is often buried in sand and obscure, and the water is not always easy to find.

17. *Ring or Ruiz Well, Inyo County* (D-4).—This well is 2 miles southwest of Surveyor's Well, in the Mesquite Flat that occupies this portion of Death Valley. The trail to it may be buried in sand, and the water difficult to find. The well is 4 feet deep, and the water good, although slightly brackish.

18. *Surveyor's Well, Inyo County* (D-4).—This well is at the northeast corner of Mesquite Flat, on the main road from Stainingers ranch to Furnace Creek. It is 19 miles southeast of Mesquite Spring, 8 miles southeast of the locality known as Lost Wagons, and 20 miles southwest of Bullfrog in an air line. The position of the well is clearly marked by camp débris. The well is 5 feet deep and the water obtained from it is good, although slightly brackish. A trail leads from it southwestward to Marble Canyon.

19. *Triangle Spring, Inyo County* (D-4).—This spring is 3 miles southeast of Surveyor's Well, on the road from Stainingers ranch to Coleman (Furnace Creek ranch), 5 miles northwest of Stovepipe Wells (No. 20), and one-half mile east of Sandy Flat. It is in a clay bank, marked by a growth of mesquite. There is a small quantity of good water.

72945—No. 224—09——3

20. *Stovepipe Wells, Inyo County* (D-4).—These wells are near the intersection of the Bullfrog-Ballarat and Stainginger-Furnace Creek roads, 25 miles southwest of Bullfrog. They are on the eastern edge and near the south end of Mesquite Flat, 6 miles southwest of Death Valley Buttes. The main road southeastward from them leads to Furnace Creek; the one to the northwest to Grapevine Canyon; the one to the northeast to Rhyolite, Nev., by way of Boundary Canyon; and the one to the southwest to Keeler, by way of Emigrant Canyon. There are two wells about 5 feet deep that yield an abundance of good water.

21. *Daylight Spring, Inyo County* (D-5).—This spring is just north of the pass in the Grapevine Range, on the wagon road from Bullfrog, Nev., to Furnace Creek and Ballarat, Cal. It is about 10 miles southwest of Bullfrog. The spring is 300 yards west of the road, on the side of the hill. The flow is about 8 barrels of good water per day.

22. *Keane Spring, Inyo County* (D-5).—This spring is on the west slope of the Grapevine Range, about 3 miles a little east of south of Daylight Spring and 4 miles northwest of the Chloride Cliff mine. It is accessible by wagon from Boundary Canyon by the road turning east up the first large wash south of Daylight Spring. The flow is 30 barrels of good water per day.

23. *Hole in the Rock Spring, Inyo County* (D-5).—This is a seep in a hole which may contain 6 or 8 gallons of water. It is about 5 miles southwest of Daylight Spring, one-half mile north of the wagon road in Boundary Canyon, and 3 miles northeast of Death Valley Buttes.

24. *Salt Creek Wells, Inyo County* (D-5).—These are two small wells in sandy earth at the foot of a low hill near the east edge of Salt Flat. They are about 5 miles southeast of Stovepipe Wells on the road to Furnace Creek ranch. The road to Ballarat turns west and crosses Salt Creek here. The water in the creek is very salty; that in the wells is brackish, but usable.

25. *Poison Spring, Inyo County* (D-5).—This spring is 11 miles east of north of the Furnace Creek ranch (Coleman) in the bottom of a very narrow limestone canyon, the deepest in the vicinity. It is 250 yards northeast of the trail from Furnace Creek ranch to Bullfrog via Indian Pass and Amargosa Desert, and is difficult to find. There is a small seep of water, which may be used in limited quantities.

26. *Springs (no name), Inyo County* (E-2).—There are a number of springs near the southeast edge of Owens Lake, which have long been known to the stockmen of that region. The springs rise from the alluvium that surrounds the lake, and the water is brackish. It is too full of mineral matter to be palatable, but serves for stock, and is a watering place on the Mohave-Keeler stage road.

27. *Cottonwood Creek, Inyo County* (E-4).—Cottonwood Creek, a stream of fine, clear water, rises in a large spring about 10 miles above

the mouth of Cottonwood Canyon and flows about 2 miles before disappearing. The canyon opens into Death Valley 11 miles southwest of Surveyor's Well and 11 miles almost due west of Stovepipe Wells. The main trail from Death Valley to Keeler via Bird Springs and Cerro Gordo follows it.

There are a number of small springs in the upper branches of Cottonwood Canyon. One is 3½ miles west of the head of Cottonwood Creek, in a side canyon just south of the main western branch. Another is 5 miles above the head of Cottonwood Creek, in the main canyon, on the main trail from Death Valley to Keeler. Still another is 1¼ miles northwest of the last, across the divide, 300 yards from the trail, in a small flat.

28. *Emigrant Springs, Inyo County* (E-4).—Emigrant Springs, which have been used since 1852, are in the northern portion of the Panamint Mountains, nearly opposite the north end of the sink of Death Valley, and about 20 miles west of the mouth of Furnace Creek. They are in Emigrant Canyon, the main pass through the Panamint Range, on the wagon road from Ballarat to Death Valley, Chloride, and Bullfrog. This road also passes Wild Rose Spring (No. 42), which is about 14 miles south of Emigrant Springs. Emigrant Springs receive their name from the fact that they were used by the early emigrants from Salt Lake City, who entered Panamint Valley by this route. They are in a canyon draining northward into Death Valley, at the north end of Tucki or Sheep Mountain, 19 miles from Surveyor's Well, in a wash at the foot of a limestone wall 20 feet high, 25 yards west of the wagon road. The supply is about 50 barrels of good water per day.

29. *Spring (no name), Inyo County* (E-4).—This is a small spring in the mountains about 3 miles east of Wild Rose Spring. It is in a canyon off the main road that passes Wild Rose Spring, about 2 miles from the road. There are a number of other springs, known to prospectors, on the west side of the Panamint Range, but they are away from traveled routes.

31. *Salt Well, Inyo County* (E-5).—This well is on the road from Furnace Creek ranch to Stovepipe Wells. It is 10 miles northwest of the ranch and 4 miles southeast of Stovepipe Wells. The water, which is too salt for human beings, but may be used by stock, is obtained from a hole in a clay bank 100 yards west of the main road. Well No. 61 is another "salt well," about 10 miles northeast of Searles, on the road between Johannesburg and Ballarat. Salt Spring (No. 75) is in the extreme southeastern end of Death Valley.

32. *Fountain Springs, Inyo County* (E-5).—There are small springs at the east edge of the butte that lies just east of the sink of Death Valley, about 6 miles north of Coleman. They are used by prospectors and miners in the Amargosa Range.

33. *Coleman Springs, Inyo County* (E-5).—Coleman was originally known as the Greenland ranch. It is now better known as the borax camp of the Pacific Coast Borax Company, and is the point from which the much advertised "20-mule teams" once hauled borax across the desert to Mohave. The springs are near the northeast end of the sink of Death Valley, at the mouth of Furnace Creek, about 50 miles by wagon road via Boundary Canyon south of Bullfrog. The water, which is abundant, is used to irrigate over 100 acres of alfalfa. It contains some saline matter, but is not unpleasant to taste and is used without injurious effects during the winter season, the only time when work is carried on in Death Valley.

The springs are about 200 feet above sea level, and are reached by two roads from Fairbanks Ranch, Nev., one running nearly due west across the Funeral Mountains to Furnace Creek and down its canyon; the other passing south of the Funeral Mountains, by way of Franklin Dry Lake, to the head of Furnace Creek Canyon.

The old route from Coleman to Mohave crosses the sink of Death Valley to Bennet's Wells (No. 44) by a road formed by crushing the hummocks of salt that cover the valley floor. From Bennet's Wells this road follows the west side of the valley to the south end of the sink, then turns southwest through Windy Gap to Lone Willow Spring (No. 65) and passes on by way of Granite Wells (No. 96) and across Willard Dry Lake to Mohave. This road is in many respects the best through Death Valley. The chief objection to it is the long drive of over 50 miles to Bennet's Wells from Lone Willow Spring without water.

Travelers are cautioned not to attempt to reach Coleman from Saratoga Springs (No. 74) by traveling down the valley of the Amargosa, unless they have a guide who knows just where to find the Confidence Springs (No. 49) in the Amargosa Range near the Narrows. These springs are 7 miles north of the ruins of the old Confidence Mill. Two trails run northward from this mill; the one that branches to the east goes to the old mines and the one to the northwest goes to the springs. As this is the only water for nearly 70 miles on a poor road the trip is a dangerous one, to be avoided under all ordinary conditions. (See "Death Valley routes.")

34. *Cow Creek, Inyo County* (E-5).—This stream, formed by the flow from constant springs, is in the canyon on the west slope of the Funeral Range, 8 miles northeast of Furnace Creek ranch. It is accessible from Death Valley and by trail from the Amargosa Desert by way of Lee's camp. There is an abundance of good water. There are springs known as Cow Springs (No. 47) on the western edge of Owens Valley.

35. *Franklin Well, Inyo County* (E-6).—A well was dug in 1852 by a Mr. Franklin near the north edge of Franklin Dry Lake, at the

foot of the south end of the Funeral Mountains, to supply water for surveying parties at work on the boundary line between California and Nevada. The old road from Furnace Creek to Fairbanks Ranch (Ash Meadows) passed this well, which was in existence in 1901, but other wells have been dug recently on the east side of Franklin Lake south of Fairbanks Ranch, so that travelers now rarely have occasion to hunt for the old well. It was originally about 20 feet deep, and its position is marked by the débris of campers.

36. *Rose Springs, Inyo County* (F-2).—These are well-known springs between Haiwee and Owens Lake and about 8 miles west of Coso Peak. The water is of excellent quality.

37. *Arab Spring, Inyo County* (F-2).—Arab Spring is on the east side of the Coso Mountains, about 9 miles southeast of Owens Lake in an air line. It is about 6 miles south of Omes, on the road to Coso, and about 11 miles due west of Darwin. The spring has long been used and is well known and easily found.

38. *Crystal Springs, Inyo County* (F-3).—Springs of excellent water are located about 6 miles north of Coso and 8 miles southwest of Darwin, on the road between the two settlements. The road from Keeler to Junction by way of Omes and Arab Spring also passes them. They have been known and used for more than forty years. There are other Crystal Springs (No. 316) eastward, in Nevada.

39. *Coso, Inyo County* (F-3).—Coso is a mining and agricultural settlement on the southeast side of the Coso Mountains. It is reached from Keeler by way of Omes, Arab Spring, and Crystal Springs, or by way of Omes, Darwin, and Crystal Springs. It is well supplied with water, and supplies for travelers can be obtained there. The water comes from granite and is of characteristic purity.

40. *Willow Springs, Inyo County* (F-3).—These springs are away from the main roads and trails, in Darwin Canyon, about 4 miles northeast of Darwin post-office, at an elevation of 3,600 feet. Their exact location can best be ascertained by inquiring at the post-office. The water is said to be excellent. There are other springs of the same name (No. 87) about 10 miles northwest of Randsburg.

41. *Spring (no name), Inyo County* (F-3).—This spring is in the pass at the north end of the Argus Mountains, on the road from Darwin to Junction. It has long been a camping place and is therefore clearly marked. The water, like that at Coso, comes from granite and is of excellent quality.

42. *Wild Rose Spring, Inyo County* (F-4).—This is a well-known spring and one of the principal stopping places on the road from Ballarat to the Panamint Valley and the north end of Death Valley. It is situated in Wild Rose Canyon, on the west side of the Panamint Range, about 20 miles north of Ballarat. There is also a road to it from Owens Lake, by way of Darwin. The water is excellent and

abundant. The spring has been a camping place for years and is easily found.

43. *Tule Springs, Inyo County* (F-5).—Tule Springs are on the western edge of the sink of Death Valley, about 5 miles north of Bennet's Wells. They are by the side of the only road that traverses the west side of the valley and are marked by small clumps of tules. The yield is small and the springs are usually partially choked with mud. The water is brackish and not so good as that at Bennet's Wells.

44. *Bennet's Wells, Inyo County* (F-5).—These watering places are on the west side of the sink of Death Valley, about halfway between its south end and the mouth of Furnace Creek, at 260 feet below sea level. They lie west of the lowest point in the sink, which is about 276 feet below sea level. A wagon road from the south end of the valley passes the wells, whose position is marked by a growth of tules, by many evidences of former camps, and by the ruins of the works of the Eagle Borax Company, which at one time operated there. The "wells," so called, are springs that were dug out and protected by barrels many years ago, and were used, until about twelve years ago, by the mule teams that hauled borax from the north end of Death Valley.

The Panamint Range is precipitous along its eastern edge, and there is but little room for a road between the foot of the range and the edge of the sink. The whole surface of the sink is covered with heavy saline deposits, which can be crossed at only a few places. The water from the old wells contains much mineral matter, mainly salt and sulphate of soda.

As there are few travelers over this route now, the springs are apt to be choked with drifting sand and must be cleaned out before a supply of water can be obtained. When the springs are cleaned the water can be used by men as well as by animals, but is not very palatable.

45. *Springs, Inyo County* (F-6).—There are a number of springs on the west side of the Black Mountains, near the summit, that give a small amount of water for several months of the year, but are generally dry during the summer. They are called springs by the prospectors, but are not to be depended on for a steady water supply.

46. *Greenwater, Inyo County* (F-6).—This is the business center of the Greenwater district. It is reached by stage or by automobile from Zabriskie, on the Tonopah and Tidewater Railroad, or from Amargosa, on the Las Vegas and Tonopah Railroad. Water is hauled to the district at present, but pipe lines are being put in.

47. *Cow Springs, Inyo County* (G-2).—These are small springs about 5 miles west of Little Lake, and are used by prospectors in that region. They are not on any main road.

48. *Spring (no name), Inyo County* (G-3).—This spring is in a pass at the north end of the Argus Mountains, on the road from Argus by way of Junction to Ballarat. As it has been used for years, it is plainly marked by the débris of camps. A road turns northward here toward Darwin and to Modoc. The water is good.

49. *Confidence Springs, Inyo County* (G-6).—These springs are about 7 miles north of the ruins of the old Confidence gold mill in the Amargosa Range, near what is called the Narrows, in South Death Valley. The old mill is about 20 miles northwest of Saratoga Springs. It was operated by the Mormons more than twenty-five years ago on silver ores taken from a mine in the mountains 7 miles north of the mill. Its situation is marked by the ruins of adobe houses that can be seen for 5 or 6 miles. These houses are on the north side of the valley, by the old wagon road. In 1903 there remained also some old feeding troughs and the wreck of the stables. There is a shaft near the ruins of the stables that is about 100 feet deep, but it contains only a heavy brine.

A trail leads from the mill northward into the mountains for 3 miles and then branches, one branch leading to the right, or east, across to the mines, where there is no water, the other to the left, or west, to the springs. This trail is obscure and the springs are small and not easily found. The water was at one time piped to the old mill and remnants of this pipe aid in finding the trail.

Between the springs and Bennet's Wells, a distance of more than 30 miles to the northwest, there are no other springs known near the road, so that the long trip from Saratoga Springs into the sink of Death Valley by this route is dangerous. (See Coleman Springs, No. 33.)

50. *Hot Springs, Inyo County* (G-7).—There are two hot springs on the eastern edge of Resting Springs Dry Lake, about 3 miles southeast of Zabriskie. These springs yield about 200 gallons per minute of water which contains, according to qualitative determinations, sulphates of soda and magnesia, some borax, and some niter. In the fall of 1908 there was an old tent at the springs, which are occasionally used for bathing purposes. The temperature of the water is about 107° F. They are about one-half mile northeast of the Tonopah and Tidewater Railroad, and a ditch and pipe leads part of the water to a watering tank beside the track.

51. *Resting Springs, Inyo County* (G-7).—Resting Springs, elevation 1,750 feet, are a well-known stopping place for all who travel in the northern part of the desert. Philander Lee has made his home here for thirty years, and his ranch of 200 acres, with shade trees, fruits, garden, and alfalfa fields, is a veritable oasis. These springs, the China ranch, and Coleman are the only places in the Death Valley region where hay can be procured. The ranch and springs are at

the south end of the Resting Springs Mountains. The waters well up from sandstone and are clear and wholesome. The Lee ranch is about 8 miles east of Zabriskie, a station on the Tonopah and Tidewater Railroad.

There are wagon roads to these springs from the east by way of Ivanpah, on the Santa Fe Railway, and thence northward to Sandy; or from Jean, Nev., on the Salt Lake road, westward to Sandy. At Sandy travelers can procure hay, grain, and other supplies. From Sandy the best route is northward by way of Manse where directions may be obtained for going to Resting Springs, about 35 miles to the southwest. There is also a road from Stump Spring directly west to Resting Springs, but it is rocky, and because of the drifting sands is apt to be dim and not easily followed.

There is an old trail from Sandy to Horsethief Spring (No. 79), thence along the north edge of the Kingston Mountains to Tecopa, and on to these springs, but it is unwise to attempt to follow this road without an experienced guide.

From Resting Springs a road runs westward across Resting Springs Dry Lake to the buildings of the old Amargosa Borax Company. There one road turns southward by way of the Ibex mine to Saratoga Springs, and another turns northward to the head of Furnace Creek. Formerly no water was procurable along the latter route between Resting Springs and Coleman, a distance of 50 miles, but conditions have been altered since the Greenwater mining camp was established.

The old San Bernardino and Salt Lake emigrant road passes these springs and goes through Emigrant Pass, just north of the ranch, and thence eastward by way of Stump Spring to Las Vegas. In the days of the old "Spanish trail" these springs were known as the Archilette. J. C. Frémont camped by them April 29, 1844, and named them "Agua de Hernández," for the survivor of a party of emigrants who were murdered there. Frémont rescued Hernández and buried his companions. He described the place as "a grassy spot, with springs and bushes, which make a camping place."

52. *China ranch, Inyo County* (G-7).—China ranch, elevation 1,357 feet, also known as Morrison ranch and Willow Creek ranch, is on the main road from Daggett to Resting Springs. On leaving Cave Springs (No. 73) and passing down the north side of the Avawatz Mountains into the bottom of Death Valley, the road branches, one fork turning to the northwest, to Saratoga Springs (No. 74), and the other continuing a little east of north, across the flat, and to China ranch. This road is frequently obscure, as it is not often traveled and the sand drifts over it. Nearly all travelers go to Saratoga Springs and stay there over night, as the road across Death Valley is very sandy. It is about 30 miles to China ranch from Cave Springs direct, and

about 20 miles by road from Saratoga Springs. To find the ranch from Saratoga Springs one may either travel eastward past the foot of the Black Mountains, and then northeastward through a pass in the lower ridge ahead, passing along the south edge of the sand dunes, or may take the road around the southern end of this lower ridge.

Travel is difficult for 1½ miles through the sand dunes and across the pass, but the route is shorter than that to the south around the ridge. From the east side of the divide the road bears sharply northeastward to the mouth of Amargosa Canyon, which can be seen from a distance. When the mouth of the canyon is reached water can be had from the river. Stock will drink it, but it is strongly alkaline. The road then runs up the canyon for about 9 miles, passing under two trestle bridges of the Tonopah and Tidewater Railroad, 2 or 3 miles north of Sperry station, then crosses the track and turns eastward to the ranch, about 5 miles above Sperry. The road thence keeps a straight course northward up Willow Creek, from which the ranch derives its water supply. The springs that furnish this water rise in Tertiary rocks, which outcrop around the ranch to a height of 500 to 600 feet.

Good hay can be obtained here, the first to be had after leaving Daggett, 110 miles south. Willow Creek furnishes sufficient water to irrigate about 100 acres of land. This ranch is one of the real oases of the desert, and travelers appreciate the cool water, the supply of alfalfa, and the shade of the fig trees.

Resting Springs are about 6 miles northeast of this ranch and Tecopa is about 7 miles east. The old emigrant road from Salt Lake passed here on its way south by way of Soda Lake and Salt Spring (No. 75) to Cajon Pass.

J. C. Frémont passed this spot April 29, 1844, on his way from Tomaso Springs (No. 103) to Resting Springs. He says of it: "The ravine [Amargosa Canyon] opened into a valley [Willow Creek], where there were springs of excellent water."

53. *Tule Spring, Inyo County* (G-7).—This spring is about 3 miles northeast of Tecopa along the roadside on the north slope of the rise near Dry Lake, between Tecopa and Manse. It has been roofed over to protect the water from cattle. The supply is not large, but the water is of fair quality. From 1 to 2 barrels at a time may be dipped from the springs.

54. *Tecopa Well, Inyo County* (G-7).—Tecopa is an old lead-mining camp at the head of Willow Creek, on the north side of the Kingston Mountains. When silver mining was active this was a large camp, with a lead smelter and many adobe houses. In the fall of 1908 mining was resumed and the locality is again a center of activity. The place is supplied with a well which stands by the

roadside about 100 yards east of the old smelter. The water is excellent, and is usually 7 or 8 feet deep.

Tecopa is about 7 miles east of China ranch, on the main road from that place to Manse, Nev. It is easily found by following the road directly up Willow Creek from China ranch to the smelter. There is also a wagon road from Tecopa to Resting Springs, which lie about 5 miles north. It is 7 miles southeast of Tecopa station, on the Tonopah and Tidewater Railroad.

55. *Grapevine Springs, Kern County* (H-2).—These springs are 4 miles north of Indian Wells station, on the road to Owens Lake. They lie near the edge of the road at the foot of the Sierra Nevada. A short distance above the springs in Grapevine Canyon running water is always to be found. The wild grapes which grow in the canyon have given it its name. The water is of excellent quality and the supply is ample for camping parties. There are other springs known by the same name near the Stainingер ranch, in the Grapevine Mountains.

56. *Freeman post-office, Kern County* (H-2).—Freeman post-office, elevation about 3,370 feet, is a well-known camping place at the point where the old emigrant road from Bakersfield, by way of Walkers Pass, reaches the desert. Here there are a number of buildings, including a post-office and a small supply store. Meals and accommodations for the night may also be obtained here. There is a fair supply of water. Roads lead from this point in several directions. One passes southward by way of Redrock Canyon to Mohave, and one by way of Haggin Well (No. 86) and Willow Springs (No. 87) to Randsburg, while another runs eastward to Searles.

57. *China Well, San Bernardino County* (H-3).—An old well was dug at the Chinese camp north of China Dry Lake when the borax deposits were worked in 1890–91. There is a road leading to it by way of Lander Well (No. 58) from Gardners station (Searles post-office). At it the roads branch, one branch leading westward to Indian Wells and Little Lake, and the other northward to Argus. The well is not kept cleaned and the water is of only fair quality.

58. *Lander Well, Kern County* (H-3).—This is an old well on the road from Randsburg by way of Searles post-office (Gardners station) to China Lake, thence northward to Argus and other points in Inyo County. The well is about 6 miles northwest of Searles, near a vacant house. The water is slightly alkaline, but of fair quality. The next water toward the north is found at China Well, 14 miles away.

59. *Searles Springs, Kern County* (H-3).—These springs are about 5 miles southwest of Searles post-office. They supply that stage station with water.

60. *Searles post-office, San Bernardino County* (H-3).—Searles post-office, locally known as Gardners station, is a well-known stage station 18 miles north of Johannesburg, on the road to Ballarat. Water is piped to it from springs about 5 miles southwest, and is sold to travelers. The water is of excellent quality, but the supply is meager. In addition to the post-office and stage station there are, at this point, a store, a telephone station, and a corral.

61. *Salt Well, San Bernardino County* (H-3).—This is a well sunk by the stage company on the road from Johannesburg to Ballarat at an elevation of 2,200 feet. On reaching the divide north of Searles post-office the traveler will see, at the foot of the grade, a dry lake covered with a white crust of borax. The well is about half a mile south of this lake, on the west side of the road. Its position is indicated by a new adobe building and by the ruins of an old adobe building and a stamp mill. The water is brackish but drinkable, and the well is supplied with a good iron pump. In Death Valley there is another "salt well," No. 31, in which the water is stronger than at this one near Searles.

62. *Quail Springs, San Bernardino County* (H-3).—These small springs are in the broken country about 8 miles east of Searles post-office. They are distant from all roads and trails and are used only by prospectors who are thoroughly familiar with the region. Other unimportant springs of the same name (No. 67) lie in the Quail Mountains, about 35 miles to the east; while at the north base of San Bernardino Mountains there is a third group of the same name (No. 210).

63. *Borax works at Searles Lake, San Bernardino County* (H-4).—Water can be obtained at the stage station at the old borax works on Searles Borax Lake, on the stage road from Randsburg to Ballarat. Water is piped to the station from springs several miles away, in the Argus Range.

64. *Slate Range gold mine, San Bernardino County* (H-4).—This mine is on the west side of the Slate Mountains and on the east side of Searles Borax Lake. Where the stage road from Johannesburg to Ballarat reaches the southwest corner of Searles Lake a well-traveled road turns eastward across the lake. This road is cut deep into the borax crusts and leads directly to the mine, whose buildings can be seen from a distance of several miles. The mining company has a number of wells that supply the camp and mill, and the miners at the camp can direct travelers to other springs in the mountains farther north.

Near the east side of the dry lake a dim road turns southward up a canyon at the foot of the range. It branches southward to Granite Wells (No. 96) and eastward to Leach's Spring (No. 69).

65. *Lone Willow Spring, San Bernardino County* (H-4).—This spring has long been known to desert travelers, as it is the first watering place north of Granite Wells (No. 96) on the road to Panamint Valley. It is about 25 miles north and a little east of Granite Wells. The spring is in a canyon in the pass between the Slate Range and Brown Mountain. It was at one time one of the stations for the "20-mule teams" hauling borax from Death Valley to Mohave, and the site of the station is indicated by old troughs and by the pipe that carries the water, whose quality is excellent, from the springs to the road. The spring was named from a lone willow that once stood near it. A short distance north of it the road branches, the eastern branch leading to the sink of Death Valley. There is no water on this road for about 38 miles, until Bennet's Wells are reached, but water may be obtained at mining camps at several points on the northern road, which leads to Ballarat.

66. *Hidden Springs, San Bernardino County* (H-5).—These springs are near the crest of the Quail Mountains, a range about 12 miles long, lying east of Brown Mountain and north of Leach Mountain. The springs are on trails known only to prospectors. They are found by following the trails of wild burros that go to them to drink.

67. *Quail Springs, San Bernardino County* (H-5).—These small springs are also in the Quail Mountains, almost due north of Leach's Spring (No. 69). They are high up in the range, away from all roads and trails, and are visited only by prospectors. The water is cold and good. They should not be confused with No. 62, which is another group of small springs of the same name, about 35 miles to the west.

68. *Fourth of July Springs, San Bernardino County* (H-5).—These form the third group of springs reported to exist in Quail Mountains. They are on the north side of the range, about 7 miles north of Leach's Spring. There is no road and no well-defined trail to them, but it is said that prospectors are able to get water for themselves and their pack animals here.

69. *Leach's Spring, San Bernardino County* (H-5).—Leach's Spring (elevation about 3,534 feet) is one of the most important camping places on the road from Randsburg to South Death Valley and to points in Nevada by way of Saratoga Springs to Resting Springs, and its water is the best to be found between Saratoga Springs and Granite Wells. Travelers are advised to make a dry camp for one night between Granite Wells and Leach's Spring. In approaching the spring from the west one ascends a steep grade through deep sand, where teams often have to double for 3 miles or more. When the summit of this grade is reached a plain road is seen leading to the right—that is, to the south—into the mountains. This road ascends steeply nearly to the main summit. At the foot of the granite pinnacles that form the axis of the range there are a few acres covered with camp

débris. Directly south of the camp is a granite bowlder over 60 feet high, which bears a striking resemblance to an elephant's head, trunk, and forefeet, stationed as if the animal were looking directly north. The locality may be further identified by the Indian arrowheads of flint and obsidian that strew the ground. The spring is in a little canyon to the west, perhaps 60 feet lower than the camping place and about 100 yards from it. Its position was once marked by a lone cottonwood tree, but this has been cut down. Four or five barrels may easily be filled in one night from this spring, and other springs are to be found for a distance of about 500 feet up the canyon. Water was once piped from the spring down to the main road for the use of the borax teams from Death Valley, and there are ruins of two corrals along this old pipe line, but there is no water near them.

On leaving the spring eastbound toward Death Valley, the traveler should follow the road down a dry wash to a dry lake, where he should turn northward along the west side of the lake, until he reaches a low divide. Owl Springs (No. 70) lie about 2 miles north of this divide. On approaching Owl Springs from the south he should keep to the main road. Several persons have been lost by turning eastward at the summit, on a road that is less plain than the one that leads to the springs.

70. *Owl Springs, San Bernardino County* (H-6).—Owl Springs are about 2 miles north of the pass between the Owl Mountains and the Avawatz Mountains. They are about 17 miles by road from Leach's Spring and about 18 miles southwest of Saratoga Springs (No. 74), and furnish the only water to be obtained between these two places. On leaving Leach's Spring the road passes along the west edge of a dry lake, beyond which it climbs a low divide at the west end of the Avawatz Range. On reaching the summit the road starts down the main wash to the north, and follows it nearly to the springs, turning to the left, or west, at the foot of the Owl Mountains proper. The springs are easily found, as they are at the foot of a monument of stones about 3 feet high, placed to mark the corners of mineral claims, and the area round about them is littered by the débris of many camps. The springs are about 6 feet deep, and the water is not too saline for comfort. A short distance to the west is a trench about 25 feet long and 10 feet deep at the deeper end. The water from this trench is in larger amount and of better quality than that of the original springs. Water can be had almost anywhere around this point, for a distance of at least 300 feet north and south, by digging shallow wells.

The road northeastward to Saratoga Springs is sometimes obscured by washouts. Death Valley is in plain sight, however, and if, after following the wash for about 10 miles, the traveler can not find the road, he should keep to the right-hand side of it until he finds a

road running directly east. This road crosses a low spur of the mountains and is the best route to Saratoga Springs. The traveler may keep on down the wash to the main valley, but will find very heavy sand and rough driving, and may be compelled to return to the southeast along the foot of the Avawatz Range until he finds the right road. In attempting to cross the Amargosa River directly below this road the traveler is in danger of getting into soft and treacherous ground.

71. *Brook Spring, San Bernardino County* (H-6).—There is a small spring at the north end of the pass between the Avawatz Mountains and Leach Mountain, to which there is no road. A wagon can be driven to it from the Leach Spring and Owl Springs road by turning off at the dry lake and going southeastward up the wash. The spring is plainly marked by the litter of prospectors' camps.

72. *Valley Springs (South Death Valley), San Bernardino County* (H-6).—Strong springs boil up in a marsh about 8 miles northwest of Saratoga Springs. Their waters are so salt as to be unfit for use. As the springs form a clear, sparkling stream for a short distance before the waters sink again, travelers are inclined to let their stock drink from them. These springs can be seen from the road that leads from Death Valley toward the sink. The ground about them appears to be firm, and in most places will support a light wagon, but it is really only a crust underlain by a deep ooze in which both men and teams may sink. There is nothing in the appearance of the ground about these dangerous spots to give warning of their nature, hence the only safe rule, when traveling in the valley away from the main trails, is to test carefully all moist areas and all ground near springs with some sort of sounding rod before walking or driving upon it.

The springs are probably nothing more than a part of Amargosa River coming to the surface, as a rock reef extends across the valley half a mile below them. The volume of water supports this view.

An analysis of the water made by Thomas Price, of San Francisco, gives the following results:

Analysis of water from Valley Springs.[a]

Sodium (Na)	29,313
Potassium (K)	1,198
Chlorine (Cl)	20,182
Carbonate radicle (CO_3)	16,690
Sulphate radicle (SO_4)	7,532
Hydrogen sulphide (H_2S)	346
Silica	240
Organic matter	223

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to parts per million and ionic form at U. S. Geol. Survey.

73. *Cave Springs, San Bernardino County* (H-6).—Cave Springs (elevation about 6,290 feet) are a well-known stopping place on the road from Daggett to Death Valley, and the water here is the last to be had before going down into the valley. The springs are near the summit of the Avawatz Mountains, and, as their name indicates, they are found in large grottos or caves. As all travelers stop here, the majority of them camping over night, the place is clearly marked by camp litter. There are two springs, each about 5 feet across and each containing about 5 feet of water. They have been cleaned out and boarded up, but are not provided with a pump. The water is excellent.

It is about 12 miles by road north from Cave Springs to Saratoga Springs in Death Valley and about 30 miles south to Garlic Spring (No. 135).

74. *Saratoga Springs, San Bernardino County* (H7).—Saratoga Springs (elevation 362 feet), situated about 20 miles west of Dumont, on the Tonopah and Tidewater Railroad, are well known to every traveler to Death Valley, as their site is the principal camping point each winter for prospectors who have claims in the vicinity. They are at the southwest edge of a black point of the Black Mountains that projects southward into the valley. The slope of the mountains east of this point is covered with sand and recedes to the north in a large cove, but part of the range that lies immediately back (northeast) of the springs is rugged and rocky. The springs can not easily be distinguished at a distance, for their location is marked mainly by the tules growing around them, and by prospectors' stone houses, which are nearly of the color of the surrounding rocks, and on approaching from the south they are hidden by a point of rocks until one is within a few yards of them.

The springs proper form a pool about 25 feet in diameter and 4 feet deep. The bottom is of white sand, which is kept in constant motion by the rising water. The overflow from the pool forms a little stream that runs northward into shallow lakes, covering 10 or 15 acres, and surrounded by tules. One might travel along the road leading from the springs northwestward to the Old Ibex mine without suspecting the existence of these lakes, as they are concealed by ridges of sand. In winter many ducks and geese may be found here, a fact appreciated by prospectors.

Even in the coldest weather the water of Saratoga Springs has a temperature of 80° or 85°; hence the springs make a bathing pool that is delightfully refreshing after long days of weary travel over the desert. It is worthy of note that the water is full of small fish, up to about 2½ inches long, of a grayish-black color. Similar fish are found at Pahrump and in other desert springs.

The road from Daggett by way of Cave Springs enters Death Valley about 5 miles southeast of Saratoga. The road from Johannesburg comes in from the west, crossing the west end of the niter beds that lie along the north flank of the Avawatz Mountains. The road to Resting Springs leads from Saratoga southeastward toward Cave Springs for about 1 mile, then turns eastward past a little lava knob in the bottom of the valley and continues in this direction toward a long spur of the Black Mountains that juts into the valley. The traveler may cross the south end of the sand dunes and climb the short grade through the low sandy pass just east of the dunes, or he may go around this spur to the south. It is a steep and hard pull through the sand to the top of the pass, but beyond the top the trail northeastward across the flat to Amargosa River is firm and no rougher than the rest of the valley. The right-hand road has no grades, as it passes around the southern end of the ridge. It crosses the Amargosa River where the latter passes close between the point of the ridge and a black butte that lies as a southeastern extension of the ridge. Thence the road swings northeastward and joins the other branch. When Amargosa River is reached it should be followed up to the canyon, where the roads are plainly marked, and thence past Sperry to the China ranch. Another road leads from Saratoga Springs northward to the summit of the Black Mountains, passing the Ibex mine, and then turning east to Resting Springs; but this road has steep grades, is very rocky in places, and in other places is covered with deep sand. The road up Amargosa Canyon is to be preferred. There is also a dim trail along the south flank of the Black Mountains, leading to the sink of Death Valley, but no water is to be had on it, except at Confidence Springs (No. 49), until one reaches Bennet's Wells, a distance of about 50 miles.

75. *Salt Spring, San Bernardino County* (H-7).—This spring of nonpotable water is in the canyon of the south branch of Amargosa River, at the east end of South Death Valley, at an elevation of 300 feet, 5 miles southwest of Dumont, on the Tonopah and Tidewater Railroad. This canyon is the pass between the Kingston and Avawatz mountains, about 14 miles southeast of Saratoga Springs. On the south side of a spur of the Kingston Mountains are the ruins of the camp of the old Amargosa gold mine, in plain view of travelers approaching from the south.

At the old mine there is a little canyon that descends sharply to the north, in which there are the ruins of a 20-stamp mill. Near the mill are two wells, protected by curbing and covered, from which water of fairly good quality may be had. This is an important thing to know, for the waters of Salt Spring are unsafe and several persons have perished from drinking them. They are supposed by miners to contain arsenic. An analysis shows, however, that al-

though they contain no arsenic they do contain very large amounts of sodium and magnesium sulphates, being in fact an almost saturated solution of Glauber and Epsom salts. Men delirious from thirst, whose sense of taste is nearly lost, may easily drink so heartily of these waters as to produce fatal results. Several other springs on the desert that are reputed to contain arsenic are similar in character.

The road from Salt Spring northward to the canyon of the Amargosa and to China ranch is covered with deep sand, very difficult to cross. The only water to be had along it is that of the Amargosa River, when it flows this far south, or at Sperry railroad station, until the ranch is reached, a drive of 16 miles. The road running westward to Saratoga Springs is rough, but the writer has always preferred to go there for a night camp, returning thence to China ranch rather than to cross the heavy sands north of Salt Spring.

J. C. Frémont camped there April 28, 1844, and speaks of the place as follows: "A very poor camping place—a swampy, salty spot, with a very little unwholesome grass. The water rose in the springs entirely too salt to drink." He says also that they found "a spring of good water a few hundred yards away in the hill." This good spring is north of Salt Spring.

76. *Sweetwater Springs, San Bernardino County* (H-7).—These springs are about 9 miles northwest of Williams Well (No. 105), at the east end of the Avawatz Mountains. They are not on a main line of travel, but are used by prospectors in the Avawatz Mountains, who are said to have recently so marked their location that they can be found by others.

77. *Kingston Springs, San Bernardino County* (H-8).—These are small springs at the north end of the Shadow Mountains, about 2 miles south of Coyote Holes (No. 78). They are not on any road and there is no well-defined trail to them. The amount of water available is small, but its quality is good.

78. *Coyote Holes, San Bernardino County* (H-8).—These are brackish springs at the north end of the Shadow Mountains near the head of the divide between these mountains and the Kingston Mountains, on the road from Death Valley to Ivanpah, by way of Clark Mountain, and on the road from Daggett to Sandy, Nev., by way of Bitter Spring (No. 136). The nearest water to the southwest is at the Riggs mine (No. 106), in Silurian Mountain, about 20 miles distant. Horsethief Spring (No. 79) is west of the road at the north end of the pass through the Kingston Mountains. There are also springs (No. 77) about 2 miles south, near the north end of the Shadow Mountains, but they are difficult to find. There is still another spring about 7 miles to the southeast, which may be reached by a dim road along the north side of the Shadow Mountains. Another watering

place of the same name, now seldom used (No. 209), lies far to the south at the east base of the San Bernardino Mountains.

79. *Horsethief Spring, San Bernardino County* (H-8).—This spring, elevation 5,600 feet, is located in the pass between the Kingston Mountains and Clark Mountain, on the road that runs from the Williams Well (No. 105) past Coyote Holes. At Coyote Holes the roads branch, one branch leading northeastward by way of Horsethief Spring to points in Nevada, the other going south of Clark Mountain to the town of Ivanpah. The road that passes this spring is very stony and rarely traveled, but the position of the spring is clearly indicated by camp litter. The spring is in shale and the water is of good quality.

80. *Cunningham Spring, San Bernardino County* (H-8).—This is a small spring on the northeast border of the Shadow Mountains, about 6 miles southeast of Coyote Holes, on the road from the latter, by way of Clark Mountain, to Ivanpah. The water is good and the location is marked by the evidences of old camps.

81. *Pachanca Springs, San Bernardino County* (H-9).—These are small springs along the northwest base of Clark Mountain. They are away from all main roads and are used only by prospectors in that range. They are not easily found without a guide.

82. *Ricardo, Kern County* (I-1).—Ricardo is the Spanish name of a ranch in Redrock Canyon on the road from Mohave to Owens Lake, where travelers sometimes stop for water.

84. *Kane Springs, Kern County* (I-2).—Kane Springs are on the west side of Kane Dry Lake and appear on some maps as the Keehn Well. The locality is a station on the stage road from Mohave to Randsburg, by way of Water station, which is about 15 miles southwest. Garlock station is about 9 miles northeast. The water of Kane Springs is slightly brackish. Kane's Wells lie south of east from these springs on a road between Barstow and Coolgardie.

85. *Garlock, Kern County* (I-2).—Garlock post-office is at the south end of the El Paso Range on the stage road from Mohave to Randsburg, by way of Water station and Kane Lake. It is a general supply point for travelers and prospectors. From this point the road begins to ascend heavy grades to Randsburg, 12 miles distant. It is therefore a favorite camping place for those with heavy loads. The water is abundant, and supplies can be obtained at the ranch. Kane Springs and Kane Dry Lake are about 9 miles southwest.

86. *Haggin Well, Kern County* (I-2).—The Haggin ranch is on the wagon road from Randsburg northwest to Freeman, about 10 miles northwest of Johannesburg, 15 miles southeast of Freeman, and 1 mile northwest of Willow Springs (No. 87), at an elevation of about 3,350 feet (U. S. Geological Survey). On this ranch there is a well that supplies good water.

87. *Willow Springs, Kern County* (I-2).—These springs are at the east end of the El Paso Mountains, about 1 mile southeast of Haggin Well and about 10 miles northwest from Randsburg, on the road to Freeman, at an elevation of about 3,850 feet (U. S. Geological Survey). On account of their proximity to the Haggin ranch, the usual stopping place for travelers in this vicinity, the springs are unimportant except to local prospectors.

88. *Summit Diggings, San Bernardino County* (I-3).—This is a small placer camp about 6 miles north of Johannesburg, on the stage road to the Panamint Valley. The camp is well supplied with water by local springs.

89. *Skilling Wells, San Bernardino County* (I-3).—This is a group of privately owned wells about 4 miles northeast of Johannesburg, near the City Wells. The water is used to supply Johannesburg and Randsburg.

90. *City Wells, San Bernardino County* (I-3).—This is a group of drilled wells on the southwest flank of Klinker Mountain, about 5 miles northeast of Johannesburg, at an elevation of 3,400 feet. Some of the wells are supplied with windmills, others have steam pumps, and the water forms the principal part of the supply for Johannesburg and Randsburg. The house and windmills make a prominent landmark, which can be seen for 3 or 4 miles. A telephone line connects the city and the wells. The stage road from Johannesburg north to Ballarat passes nearly 3 miles west of the wells. The road from Johannesburg to Pilot Peak approaches within half a mile of them, then turns down a canyon to the southeast toward Willard Dry Lake. (See Blackwater Well, No. 95.)

91. *Squaw Spring, San Bernardino County* (I-3).—This spring is about 4 miles due east of Johannesburg, at an elevation of 3,475 feet, and is most easily reached by going from Johannesburg eastward to the City Wells, then southeastward on the Pilot Peak road to the head of the canyon just below the City Wells. There a plain road skirting the side of the mountain to the south leads to the Squaw Spring. It is not on a main line of travel and is used only by local prospectors. The water is good.

92. *Blackhawk Well, San Bernardino County* (I-3).—Blackhawk Well, elevation 2,665 feet (U. S. Geological Survey), lies at the south end of Red Mountain, about 6½ miles northeast of St. Elmo and about 11 miles by road southeast of Johannesburg. After leaving Johannesburg, on the Pilot Peak road, a road that leads to Blackhawk Well turns to the south beyond the City Wells. The well is not in general use by travelers, because it is not on a main road, but it is occasionally used by those who go from Johannesburg to Barstow by way of Fremont's Peak and the Black Range. The water is excellent, and miners haul it to their camps.

93. *Bedrock Spring, San Bernardino County* (I-3).—This small but excellent spring is on the north side of Klinker Mountain on the old wagon road from Johannesburg through Bedrock Canyon to Searles Lake, about 10 miles northeast of Johannesburg, at an elevation of 3,225 feet (U. S. Geological Survey). This road is rarely used except by freighters who are well acquainted with the country, because no water can be obtained along it for a stretch of 30 miles or more. Travelers are advised to follow the main road by way of Searles post-office.

94. *Well at Willard Lake, San Bernardino County* (I-3).—This is a well that was dug years ago at the northeast end of Willard Dry Lake, alongside the old Death Valley borax road, at an elevation of about 2,520 feet. It gave a good supply of slightly brackish water. The well is now partially caved in and should be cleaned out. It is not on any of the main lines of travel, but is some distance south of the road from Johannesburg to Blackwater well.

95. *Blackwater Well, San Bernardino County* (I-4).—This well is one of the important camping and watering places on the main road from Johannesburg to Death Valley and Resting Springs. It is on a divide about 18 miles east of Johannesburg. The road eastward from the town runs past the railroad roundhouse toward the City Wells, which can be seen toward the northeast. About 2 miles from Johannesburg it forks: the left branch, bearing to the north, goes to Ballarat via Searles Lake; the right-hand branch runs directly toward the City Wells, and when nearly south of them turns down the canyon to the southeast. At the foot of the hill this road runs eastward to the base of Lava Mountain and north of Willard Dry Lake. In the distance a low ridge is seen, lying at right angles to the road—that is, in a north-south direction. Blackwater Well lies nearly at the crest of this ridge. The main road crosses several of the old Death Valley borax-works roads, which come in from the south in the direction of the dry lake, and these roads must be avoided, as there is no water on them for 25 miles in either direction. When the summit is reached the well can be located by the bare ground in its neighborhood, from which campers have stripped all vegetation. The well, which was dug years ago by government troops, is about 15 feet deep and is in the form of a shaft, 5 by 7 feet. The water in it is usually from 2 to 3 feet deep. When the well has not been used for a long time the water becomes dark colored and ill smelling and is often foul from the bodies of desert rats and rabbits, but when freshly cleaned it is sweet and wholesome and free from alkali. It is probable that if the well were deepened a much more abundant supply would be procured. Water was at one time piped down the slope for a distance of one-half mile to the old Death Valley borax-works road. The remnants of the trenches and pipes aid in locating the well.

A road that turns off at the wells crosses the divide to the east and extends to Copper City, a small mining camp. The road to Death Valley starts northward from the well, reaching the summit in about one-half mile, and the north end of a black lava ridge in about 3 miles. There it turns east directly toward Pilot Peak. From the foot of the lava point it is a heavy climb for 6 miles up the mountain to the base of Pilot Peak, where Granite Wells are located.

96. *Granite Wells, San Bernardino County* (I-4).—One of the best-known camping and watering places on the road to Panamint and Death Valley is at Granite Wells, just west of Pilot Peak, a very prominent landmark in the Mohave Desert. At the base of the peak is a knob of gray granite, north of which are a frame house and the remnants of several stone structures. The best water is found in a short tunnel run into the granite 50 feet northeast of the cabin. At the end of this tunnel is a sump hole, about 3 feet deep, in which the water collects. This water, coming from the granite, is cool and pure, but the sump often needs cleaning out. About 2 barrels can be got here in twenty-four hours. A quarter of a mile down the hill southeast of the granite knob are an old well and an open earth cut that was made to develop water. This cut is just east of the well and may be clogged with sand, but it can be cleaned out in a few hours, and several barrels of water sufficiently good for stock will collect during the night.

From the wells the road passes northward over a low divide and then down to the foot of the Slate Range, meanwhile keeping just west of a long ridge formed by a flow of lava. At the north end of this ridge, which is known as Black Point, the road turns eastward to Slate Range Dry Lake. There the Panamint road branches northward to Lone Willow Spring, while the road to Nevada and South Death Valley runs eastward to Leach's Spring.

There are many dim roads that turn off westward toward the Slate Range and Searles Lake, but no water is to be found along them and they are not plainly marked, whereas the main roads described are well marked.

On the road to Ballarat and the Panamint Valley there is no water to be had until Lone Willow Spring is reached, high up in the pass between the Slate Mountains and Brown Mountain, a distance of nearly 30 miles over a road that is both sandy and rocky.

The road to Death Valley by Leach's Spring is good up to a point within 6 miles of the spring, but this last 6 miles is all upgrade through exceptionally deep sand. Therefore one should travel as far as possible from Granite Wells, make a dry camp, and pull up the grade to the spring early in the morning.

97. *Pilot Spring, San Bernardino County* (I-4).—This spring is between 3 and 4 miles southeast of Granite Wells, near the top of the

hill on the old road to Copper City. The water supply is small and the spring is often choked up, because it is rarely used.

98. *Lead Spring, San Bernardino County* (I-4).—This is a small spring discovered by prospectors who found outcrops of lead ore near it. It is about 4 miles southeast of Black Point, a dark lava knob at the north end of the Pilot Peak Range, where the road from Granite Wells to Leach's Spring turns to the east. In 1904 there was at this point a guideboard that gave directions for finding the spring.

99. *Wheeler Spring, San Bernardino County* (I-6).—This spring is at the south end of Leach Mountain, in the pass between this mountain and the Avawatz Mountains. Brook Spring is 3 miles to the north and Whitney Spring (No. 100) is 5 miles to the southeast. None of these springs is on a main road. They are used only by prospectors and can be located only by the débris of former camps near the dim trail that runs through this pass.

100. *Whitney Spring, San Bernardino County* (I-6).—This spring lies about 5 miles southeast of the pass between Leach Mountain and the Avawatz Range. It is on the north side of Granite Mountains near their base, and the water rises from the granite. The supply is not large but the quality is excellent. Wheeler Spring is about 5 miles northwest and Cave Springs are about 12 miles northeast. There are no good roads or trails to this spring, but it may be found by following the dim trail that leads through the pass at the east end of Leach Mountain.

101. *Government well at Tiefort Mountain, San Bernardino County* (I-6).—It is said that there is still in existence an old well dug by government troops years ago, near the northeast edge of "No. 4 Dry Lake," about 9 miles north of Langford Well (No. 134) and about 5 miles northeast of Garlic Spring (No. 135). This old well is on the road from Daggett to Death Valley, at the southwest end of Tiefort Mountain, and is the only watering place the traveler finds along this road until he reaches Cave Springs, a distance of about 25 miles. The well is reported by recent travelers to have been partly filled by wash carried over it during cloud-bursts, so that water can not be obtained without practically redigging it.

102. *Harper's camps, San Bernardino County* (I-7).—These mining camps are in the south end of the Avawatz Range. A well-traveled road leads to them, branching off the Silver Lake road to Crackerjack, where it crosses the old Mormon trail. This point is about 7 miles northwest of Silver Lake, and is marked by a plain signboard. The road runs northwestward up the flank of the mountain to the largest canyon, and follows up this canyon to the north.

About 4 miles up the canyon the road forks again, the point being marked by a sign reading "Harper's south camp 1 mile" and "Har-

per's north camp 4 miles." Arrows on the signboard indicate the roads.

At the south camp water has been developed by tunneling into the granite. The supply is about 4 miner's inches and is excellent in quality. The north camp is in Arrastre Gulch, where there is a large supply bubbling up from beneath limestones. Arrastre Gulch is the main canyon opening onto the desert at the east end, almost due west of the siding at Riggs, on the Tonopah and Tidewater Railroad.

103. *Tomaso Springs, San Bernardino County* (I-7).—This group of springs lies at the northwest end of the Soda Lake Mountains, about 10 miles northeast of Bitter Spring (No. 136), on the old emigrant road to Salt Lake. Their permanency is indicated by the fact that J. C. Frémont mentions them in his journal. He camped here on his homeward journey from California April 25, 1844, and reported that he found the springs "dug out by the Indians or travelers" and "the waters cool and refreshing." The site of the springs is well marked by camp débris, and the water is good.

104. *Silver Lake, San Bernardino County* (I-8).—This town, on the Tonopah and Tidewater Railroad, is 40 or 50 miles north of Ludlow, on the Santa Fe Railway. It is the supply point for the Crackerjack, Chisholm, Harper, and other mining districts to the east and west. Stages and automobiles run to Crackerjack. Silver Lake has post-office, express, and telegraph offices. The railroad company pumps water from a well about 200 feet deep and pipes it through the town. The water is slightly brackish, but is used freely by everyone. The lake from which the town takes its name is about one-fourth of a mile to the west. It is a shallow, intermittent body of water, formed in a bowl in the desert by the overflow of Mohave River during seasons of unusually high water. Shallow wells sunk near the edge of this lake give an abundant supply of brackish water.

105. *Williams Well, San Bernardino County* (I-8).—There is a well at the edge of Silurian Dry Lake, west of the Riggs mine and well, on the road that leads from Daggett and Soda Lake northward to Death Valley and northeastward to points in Nevada by way of the Kingston Mountains. From this point it is about 25 miles by road southward to Government Well, at Soda Lake (No. 139), and about 20 miles southwestward to Tomaso Springs. Miners here and at Riggs can give information about trails and conditions of water supply farther north.

106. *Riggs Well, San Bernardino County* (I-8).—There is an excellent well at the Riggs gold mine, 2 miles east of Riggs station, on the Tonopah and Tidewater Railroad, and near the east end of Silurian Mountain, a small range lying between the Avawatz and the Shadow mountains. The mine has been in operation for some time

and the camp is a stopping place for all travelers. The road to this camp from Daggett, instead of going by way of Coyote Lake, crosses the east end of Alvord Mountain and goes on by way of Bitter Spring to the east end of the Avawatz Mountains, where it joins the road from Balch on the Salt Lake route. The latter road runs northward from Balch, past Government Well at Soda Lake.

107. *Toltec, San Bernardino County* (I-8).—This is a camp occupied by some turquoise miners. It is at the south end of Shadow Mountains, and about 6 miles northeast of Halloran Springs. The camp is supplied with good water, which comes from springs in the mountains near by.

108. *Halloran Springs, San Bernardino County* (I-8).—Halloran Springs have been for years a camping place for travelers en route from Soda Lake to Ivanpah Mountain and Clark Mountain over the old Ivanpah trail. The springs are near the north end of a little unnamed butte that lies about 10 miles northeast of Dante Springs (No. 140), and are readily located by the quantities of camp rubbish in the vicinity.

109. *Spring, San Bernardino County* (I-8).—Several desert prospectors have reported that there is a spring about 8 miles southeast of Halloran Springs, and that the water is good, but there are no traveled roads or trails to it.

110. *Crater Spring, San Bernardino County* (I-9).—There are said to be springs at the Three Ash Craters, a prominent group of extinct volcanoes in the desert at this point. They are not near the main-traveled roads and are visited only by prospectors. No accurate description of them has been obtained.

111. *Valley Wells, San Bernardino County* (I-9).—Valley Wells, known also as Rosalie Wells, are situated near the border of Ivanpah Mountain, on the main road from Soda Lake and from Kessler Springs (No. 112) to the old copper mine in Ivanpah Mountain. The wells were dug by a mining company and supplied enough water to operate the smelters that were once in use on the copper ores of this district.

112. *Kessler Springs, San Bernardino County* (I-9).—Kessler Springs, elevation 5,500 feet, are well known to most desert travelers, as they are on the old road from Daggett by way of Soda Lake to the New York Mountains. They are at the south end of Ivanpah Mountain, about 6 miles northwest of Cima station, on the Salt Lake Railroad. A road leads from them to the town of Ivanpah, about 10 miles northeast, and to Rosalie, about 12 miles northwest. The water is abundant and excellent.

113. *Cottonwood Spring, San Bernardino County* (I-10).—This spring is on the north side of the New York Mountains, near the Salt Lake Railroad, and is used principally by miners and pros-

pectors in this region, as it is not on any main line of desert travel. There are several springs of this name in the area discussed, so that the name alone is not distinctive. About 30 miles to the southwest are Cottonwood Springs (No. 162), which are also used as a watering place.

115. *Ivanpah Well, San Bernardino County* (I-10).—A well has been dug in the bottom of the south end of Ivanpah Dry Lake, about a mile east of the town of Ivanpah, at an elevation of 4,230 feet (Santa Fe Railway). The town is the present terminus of the Santa Fe branch road from Goffs. This well formerly supplied a stage station on the old road from Barnwell, Cal., to Manse, Nev. It is about 140 feet deep and is provided with a windlass for drawing water. The water is only slightly saline. It is still used by those who drive north from Barnwell.

116. *Saccatone Springs, San Bernardino County* (I-10).—These are small springs on the north side of the New York Mountains and are of importance only to local prospectors and miners, as this region is so thickly settled now as to offer no difficulties to the traveler.

117. *Water Station, Kern County* (J-1).—This is a well-known road ranch and old stage station, about 9 miles northeast of Mohave, on the road from Mohave to Keeler. Good ranch houses, an abundance of water, and accommodations for travelers will be found at the station.

Frémont stopped at the springs here early in April, 1844, on his way from Cameron Salt Lake east by way of the "Desert Buttes" to Mohave River.

118. *Desert Wells, Kern County* (J-2).—This is an old stage station on the Mohave and Randsburg stage road about 6 miles northeast of Water station, and 15 miles from Mohave, the junction of the Southern Pacific and Santa Fe railroads. A road runs eastward from these wells to Francis Well (No. 119), on the railroad from Kramer to Randsburg.

119. *Francis Well, San Bernardino County* (J-3).—This is a drilled well, equipped with a pumping plant, on the railroad between Kramer and Johannesburg, about 12 miles north of Kramer, at an elevation of 4,220 feet (Santa Fe Railway). It is a watering place for travelers from Mohave by way of Desert Wells and for those going by team from Kramer to the mines farther north.

120. *Goleta Spring, San Bernardino County* (J-3).—At the southeast base of Fremont Peak there is a spring whose name dates back to the time of Frémont's last homeward trip across the Mohave Desert. It is just west of the old road that runs from Randsburg to Barstow by way of Harper Dry Lake and Black ranch (No. 123). Another old road branches from this main road about 3 miles west of Harper Lake and runs southward to Harper station, on the Santa Fe

Railway. There has been very little travel over any of these roads for a number of years.

121. *Star Springs, San Bernardino County* (J-4).—These springs are about 3 miles east of the south end of Fremont Peak, on the east side of the pass through which the road from St. Elmo to Harper runs. They are along the west base of the Black Range. As there is good water at Goleta Spring, on the wagon road directly west, the Star Springs are not important to travelers.

122. *Grant Springs, San Bernardino County* (J-4).—There are reported to be good springs at the Grant Corral, 1½ miles northwest of the Black ranch, on the old San Bernardino and Panamint road, at the point where it passes Harper Lake. The springs are between Harper Lake and the low range of mountains to the north. As there is a good supply of water at Black's Well (No. 123), these springs are not important.

123. *Black's Well, San Bernardino County* (J-4).—This well is about 7 miles northwest of Hinkley, at the east end of Harper Lake, on the old road from Victorville and Hinkley stations to Death Valley formerly known as the San Bernardino and Panamint road. An adobe house, which served as the headquarters of an old cattle ranch, is still standing near the well and is in good condition. The well is covered with a platform and the water stands within a few feet of the top. It is dark colored, but nearly free from saline matter.

The cottonwood trees that surround the well and house can be seen from a distance of several miles and serve to guide the traveler to the water. To the northwest, across Harper Lake, no water is to be had until one reaches Fremont Peak, but toward the north water may be obtained at the mining camps in the Black Mountains.

124. *Murphy's Well, San Bernardino County* (J-4).—This well is at the Murphy Dry-Placer Camp, about 15 miles northwest of Barstow and about 6 miles southwest of Coolgardie. Directions for finding it are not easily given, because this region for miles around has been gridironed with roads and trails over which the miners haul water to their placer camps. It is on one of the roads from Barstow to Copper City, and usually there are miners at some of the placer workings who can direct travelers to the well.

126. *Coolgardie, San Bernardino County* (J-5).—Coolgardie is the name of a small mining settlement, the cabins of the miners being scattered over several square miles of dry-placer workings. Water may be procured at the camp from the miners, who bring it in from the springs near by. The road to Coolgardie is the left-hand or west branch on the second summit north of Barstow and west of Kane's Wells (No. 129). The right-hand road at this point leads east to Kane's Wells.

127. *Well, San Bernardino County* (J-5).—This well is at the southwest end of Coolgardie Lake, the easternmost of the three dry lakes in this township. It is by the side of the road to Copper City and is readily found. The well is dug in the playa deposits and the water is of fair quality, being only slightly brackish.

128. *Indian Spring, San Bernardino County* (J-5).—This spring is about 12 miles north of Kane's Wells (No. 129) and about 4 miles north of some dry-placer mines. A road leads northward to it from Kane's Wells and thence westward by way of Coolgardie Dry Lake to Copper City, but it is a road over which there is but little travel. The spring is utilized by miners who work the dry gold placers of that region. The water is better than that along the dry lakes to the southwest, as it flows from granite. Another Indian Spring (No. 150) lies about 75 miles westward, near Rosamond Station, on the Southern Pacific Railroad.

129. *Kane's Wells, San Bernardino County* (J-5).—These wells (Pl. III, A) are about 22 miles north of Barstow on the road to Coolgardie and Copper City. After leaving Barstow the road crosses two divides, and a short distance beyond the second divide turns northeastward to the head of a little canyon that runs eastward. Kane's stamp mill and wells are about one-fourth mile down this canyon and can not be seen by the traveler until he is near the house and the mill. There are two good wells here, both boarded up and supplied with pumps.

On looking down the canyon from the mill the traveler may see Coyote Dry Lake in the desert below, but to reach this lake or to go northward he should return to the head of the canyon. The main road leads northward from this point past the placer camps to Indian Spring and Copper City; the middle road at the summit leads northwestward to Coolgardie, about 7 miles distant. On continuing northward and following the crest of the divide on the easternmost trail, the traveler will find a road that turns eastward down the canyon. This road leads to Coyote Dry Lake. On the main Copper City road to the north, beyond the dry placer works, another road turns off toward the east, running to Paradise Springs (No. 130), but it was so badly washed out by cloud-bursts in 1905 as to make these springs difficult to find. Kane Springs (No. 84) lie west of Randsburg, while Kane's Spring (No. 176) is about 9 miles southeast of Newberry Station.

130. *Paradise Springs, San Bernardino County* (J-5).—Paradise Springs are a favorite stopping place with prospectors who know the way to them, as there is generally sufficient grass around them to afford good grazing. The best way to reach them from Kane's Wells is to follow the road from that place directly north for about 3

miles—that is, to a point about 1 mile north of the dry-placer camp. The road then turns to the east and descends along a dry wash to the foot of the main range. Here it turns to the north across a wide flat and curves finally into a large cove, in which the springs are found. The water is clear, pure, and warm, and the developed supply amounts to 2 or 3 miner's inches.

A water appropriation has been filed on the springs by the Paradise Mountain Mining and Milling Company, and a gravity pipe line laid to their workings, about 2 miles southwest.

131. *Canyon Spring, San Bernardino County* (J-5).—This spring is in a main canyon on the east side of an unnamed mountain northwest of Coyote Dry Lake. It can not be located by land lines with certainty, but it is probably in the NE. ¼ sec. 7. It is not on a main line of travel, but is near what is known as the old trail from Barstow by way of Paradise Springs to Death Valley. It is 6 miles east of Paradise Springs and about 5 miles northwest of the north end of Coyote Lake. There was once a road from Daggett along the west side of Coyote Dry Lake, which led to Canyon Spring and to Garlic Spring (No. 135). These roads are rarely traveled now by wagon and are probably obliterated for long distances by drifted sand. Usually they are less obscure near the spring than at greater distances from it. The supply of water is not large, but the quality is good.

132. *Willow Spring, San Bernardino County* (J-5).—There is a small spring of brackish water in the foothills at the north end of Coyote Lake. In 1900 water was running there in some quantity, but early in 1905 the spring could not be found, because of the effects of a storm in the vicinity some time before. It should be about 2 miles west of the main road that crosses Coyote Lake en route from Daggett to Death Valley. Its position is noted, in order that prospectors and others who traverse this country may be on the lookout for it. It often happens that springs are covered by the wash of storms and disappear temporarily, but later reappear near the old location.

133. *Coyote Well, San Bernardino County* (J-5).—Coyote Well, the first camping place on the road from Daggett to Death Valley, is about 17 miles northeast of Daggett. The traveler may go from Daggett by way of Otis and pass east of the Calico Range to the well, keeping in the open country all the way, or he may take another road which leads from Daggett northward by way of Borate. From Borate this road follows the narrow-gage railroad of the Pacific Borax Company to the divide of the Calico Mountains, then continues down the mountain slope to the main valley, where it turns eastward, following the valley to the open country, and thence northeastward to the well.

The well (Pl. III, B) is easily found, as it stands by the roadside at the south end of Coyote Dry Lake. It is about 15 feet deep and

A. KANE'S WELL.

B. COYOTE WELL.

is covered with a platform. There is a windlass and an iron pump at the well, but the pump handle was broken some time in the spring of 1905 by vandals. The water is abundant but it is slightly brackish. Small sulphur springs issue from the hills about 2 miles west of this well, but the water is small in quantity and is fit only for stock. The next water to be found on this road is about 14 miles farther north, at Langford Well (No. 134). Two other watering places, known as Coyote Holes (Nos. 78 and 209), lie about 70 miles to the northeast and to the southeast, respectively.

134. *Langford Well, San Bernardino County* (J-6).—One of the important watering places on the road from Daggett to Death Valley is a well at the southwest corner of Langford Dry Lake, about 14 miles north of Coyote Well. The water here is the best to be had between Daggett and Cave Springs. The well is about 40 feet deep and is protected by board covering. A good iron pump was put in early in 1904, but was broken in the fall of the same year by vandals. The well is readily found, as it is close by the roadside and is surrounded by the débris left by numerous camping parties.

135. *Garlic Spring, San Bernardino County* (J-6).—This is a well-known spring on the road from Daggett northward to Death Valley. It is at the west edge of the range of mountains that lies next north of Langford Dry Lake and south of Tiefort Mountain, at an elevation of about 2,455 feet. The majority of campers stop at Langford Well and do not stop at Garlic Spring, because the water there is strong with sulphur, and sodium and magnesium sulphates.

136. *Bitter Spring, San Bernardino County* (J-7).—This spring is near the southeast end of Bitter Lake, on the old emigrant road to Salt Lake City. It is the first watering place the traveler reaches on this road after passing Alvord Mountain. It is also on the road from Daggett to the Shadow Mountains, and is one of the principal stopping places on that road. It has been known since 1852. The water contains too much sodium sulphate to be wholesome, but it can be used.

137. *Cronese Spring, San Bernardino County* (J-7).—This spring is at the southeast end of Cronese Dry Lake, at the southwest base of the Soda Lake Mountains. It is well known to desert prospectors, but not being near one of the principal routes is not known to casual travelers. The water is slightly brackish but not unwholesome. By digging a shallow well here enough water could probably be developed to irrigate a few acres.

138. *Barrel Spring, San Bernardino County* (J-7).—This spring, at one time an important point on the old emigrant road to Salt Lake, is near the south end of the Soda Lake Mountains, about 15 miles east of Afton and 10 miles southwest of Government Well, at

Soda Lake (No. 139). It is near a rocky point where the road from Daggett north to Government Well rounds a spur of the Soda Lake range. It is a small spring, protected by a barrel sunk in the ground. Since the building of the Salt Lake Railroad it has lost its importance to travelers.

139. *Government Well at Soda Lake, San Bernardino County* (J-8).—At Soda Lake, a station on the Tonopah and Tidewater Railroad, is one of the wells dug by government troops forty or fifty years ago. It is on the eastern branch of the old emigrant road from San Bernardino to Salt Lake City by way of Mohave River, and is near the west edge of the sink of the Mohave, at the eastern base of the Soda Lake Mountains. The well is easily found, because its position is marked by the ruins of the old adobe and stone buildings erected by the troops. The water is a part of the underflow of Mohave River, and is of fair quality, in spite of the heavy deposits of soda that whiten the surface all about it.

The well is a pool lined with stone, about 5 by 8 feet in dimensions and 3 feet deep. It is near the edge of some tules about 150 feet southeast of the largest stone building. The buildings are on the north side of a limestone knob, and the traveler can not see them from the road until he is within 100 yards of them. This knob, however, near the middle of the western edge of Soda Lake, serves as a guide to their position. The tules, which can be seen from a distance as one approaches the well, also aid in finding it.

The next water north is at Dante Springs (No. 140), on the road to Halloran Springs and Ivanpah.

A road leads northward from Government Well by way of Silver Dry Lake to Death Valley. It passes between the Avawatz and Shadow mountains, but there is no water to be had along it until one reaches Williams Well, at the west end of Silurian Mountain, a distance of about 25 miles, unless one turns off to Berry or to Silver Lake.

140. *Dante Springs, San Bernardino County* (J-8).—These springs are, as near as can be determined, in the southeast quarter of section 28. They are on the north side of the butte that stands at the northeast end of Soda Lake, on the road from Government Well, at Soda Lake, to Halloran Springs and Valley Wells (Rosalie). It is about 12 miles from Dante Springs to Halloran Springs. The water is of good quality, but its quantity is not large.

141. *Borax Well, San Bernardino County* (J-8).—This is a well dug by miners on the east side of Soda Lake, about 7 miles nearly due east of Soda Lake station. A road leading from Balch, on the Salt Lake Railroad, to Dante Springs passes it. The well is about 20 feet deep and the water is soft and of fair quality. Analysis

shows the presence of borax and of a small amount of sodium sulphate.

142. *Well near Soda Lake, San Bernardino County* (J-8).—A well is reported to exist near the south end of Soda Lake, 2½ miles southeast of Epsom station, on the Salt Lake Railroad. The supply of water is said to be good, but the well is not of great importance, because travelers can obtain water at a more convenient point, Balch station, where most of the desert wagon roads leave the Salt Lake Railroad.

143. *Spring near Soda Lake, San Bernardino County* (J-8).—Prospectors report that there is a good spring at the north end of Old Dad Mountains, about 4 miles southeast of Balch.

144. *Marl Springs, San Bernardino County* (J-9).—There are springs of good water at the north end of a small butte about 9 miles southwest of Cima station, on the Salt Lake Railroad. They are on the old road from Kessler Springs to Soda Lake. They have been used for years by prospectors, and are marked by the traces of old camps beside the road.

145. *Government Holes, San Bernardino County* (J-10).—This watering place is 5 miles northeast of Elora, on the Salt Lake Railroad. More than forty years ago a military road extended from Fort Mohave, Ariz., across the desert to Mohave Sink and up Mohave River. This supply road passed the old Piute Springs (No. 149), the Mid Hills, and Soda Lake, and at old Camp Cady on Mohave River joined the emigrant trail from San Bernardino to Salt Lake.

One of the wells dug along this road by the troops, years ago, is known as Government Holes. The well stands at an elevation of 5,100 feet, on the west side of the Mid Hills, a range of low buttes just east of the north end of the Providence Mountains and south of the west end of the New York Mountains. The tops of the Mid Hills show granite pinnacles, and the well at their base is plainly marked, as various desert roads converge to it. The well is protected by a corral, and a ranch house stands near it. The water is very good.

146. *Out West Well, San Bernardino County* (J-10).—This is a well dug at the camp of the Out West Mining Company along the west side of the Mid Hills, about 4 miles in an air line southwest of Government Holes (Pl. II, *B*). A well-traveled wagon road leads westward from Government Holes to the head of Black Canyon and down the canyon for about 1 mile. It then turns back toward the east for a few rods and northward to the Out West camp. The camp is marked by a stone house and by the old frames of tent houses. The well is dug in granite and is protected by curbing. It is about 40 feet deep and usually contains 15 feet or more of sweet, pure water.

There is no other water to be had along a road that runs southward through Black Canyon until the old mining camp of Providence (No. 164) is reached, about 25 miles northwest of Fenner.

147. *Rock Springs, San Bernardino County* (J-10).—These springs lie 6 miles southeast of Government Holes, on the old government road running to Fort Mohave, Ariz. They are easily found and the water is of good quality, although the quantity is not large.

148. *Vontreger Springs, San Bernardino County* (J-11).—These springs are about 9 miles north of Goffs Station (Blake post-office), on the Santa Fe Railway, in the low hills east of the branch line that runs from Goffs to Barnwell, in a canyon on the south side of the summit of the hills. They are easily found, and their water is abundant and good. There is no other water on the road north of these springs until Barnwell is reached.

149. *Piute Springs, San Bernardino County* (J-11).—These are well-known springs in Piute Pass, about 15 miles north of Goffs Station, on the Santa Fe Railway. They are on the old military road that leads from Fort Mohave to Government Holes, and roads lead to them from Goffs, Ibis, and Blackburn Siding. There are other springs of the same name, about 20 miles northward, just across the state line in Nevada.

150. *Indian Spring, Kern County* (K-1).—This is a strongly flowing spring, about 3 miles northeast of Rosamond Station, on the Southern Pacific Railroad. It is near the northwest edge of Rosamond Dry Lake, on the wagon road that runs from the railroad to Buckhorn Spring (No. 152). Water fit for stock can be obtained here. There is another spring (No. 128) of the same name, on a little-traveled road between Daggett and Copper City.

151. *Rodriguez, Kern County* (K-2).—This is a pumping station on the Santa Fe Railway, 18 miles east of Mohave. The railway company has sunk a well 40 feet deep at the west edge of Rodriguez Dry Lake, and procured an abundant supply of water of fair quality.

152. *Buckhorn Spring, Kern County* (K-2).—Buckhorn Spring has been well known to desert travelers for over thirty years. It is on the west side of Rodriguez Dry Lake, about 7 miles south of Rodriguez Station, on the Santa Fe Railway, and about 15 miles east of Rosamond Station, on the Southern Pacific. A cabin belonging to a prospector who has lived there for years stands near the spring, which is therefore easily found. The water, although slightly brackish, is of fair quality. There are other springs about the lake border. One of these is about 6 miles southeast of the wells, on the east edge of the lake, the road to it passing around the margin, and another is about 3 miles north.

153. *Spring at Rodriguez Lake, Kern County* (K-2).—A spring exists on the west edge of Rodriguez Lake, about 4 miles northeast of

Buckhorn Spring. It is said to be a little salty, but it can be used by men as well as animals. It is not important, however, because Buckhorn Spring is near by.

154. *Flowing Wells, Kern County* (K-2).—Artesian wells were drilled several years ago on the east side of Rodriguez Dry Lake, 7 miles east of the Santa Fe station of the same name, about 15 miles by road southwest of Kramer, and about 7 miles northeast of Buckhorn Spring. The water is reported to be abundant and of excellent quality, and the wells are at the northeast end of a considerable area in which artesian waters have been developed.

155. *Kramer, San Bernardino County* (K-3).—Kramer (elevation 2,479 feet, according to Santa Fe Railway) is the junction point of the Santa Fe main line and the branch leading north to Randsburg and Johannesburg. It is about 174 miles from Los Angeles by way of Barstow, and 38 miles east of Mohave. The railway company has recently drilled a well at this point, and water can now be procured here by travelers. A good wagon road parallels the railway to Randsburg, on which water may be obtained at Fremont station, Francis Well, and St. Elmo. A wagon road also leads from Kramer to Victorville, about 35 miles southeast.

156. *Well at Harper Lake, San Bernardino County* (K-4).—There is a well about 1½ miles south of Black's ranch and about one-half mile east of the road from Hinkley to Black's. The well is in an open alkali flat and was once used for watering the ranch stock. The water is brackish and the watering place is not important, for Black's Well is near by.

157. *Hinkley Well, San Bernardino County* (K-4).—Hinkley is a pumping station on the Santa Fe Railway about 10 miles west of Barstow. There is no town at this point, but the site is marked by the pump and section houses. The company has a well 70 feet deep from which to fill its tanks. The traveler may procure a supply from these.

158. *Newberry Springs, San Bernardino County* (K-6).—There are large warm springs about 600 yards south of Newberry station on the Santa Fe Railway. The water is clear and pure and is used by prospectors en route to the mountains farther south. The Santa Fe company has built a circular masonry reservoir about the springs and pumps from them through an 8-inch pipe line. The water is hauled in tank cars to supply locomotives at Ludlow and Bagdad.

160. *Willow Springs, San Bernardino County* (K-9).—These springs are at the southwest end of Granite Mountain and are marked by a clump of willow trees. They are about 20 miles northwest of Cadiz station on the Santa Fe Railway and at about the same distance southwest of Kelso station on the Salt Lake Railroad. A pros-

pector's trail leads to them from Kelso along the east side of Granite Mountain.

161. *Cove Springs, San Bernardino County* (K-9).—These springs are at the southeast edge of Granite Mountain, about 6 miles south of Cottonwood Springs (No. 162). There is a road from them to Kelso station on the Salt Lake Railroad. The quantity of water is limited, but the quality is excellent, as the springs have their source in granite. They should not be confused with Cave Springs (No. 73) in the Avawatz Mountains.

162. *Cottonwood Springs, San Bernardino County* (K-9).—These springs, which yield good water, are at the southwest end of the Providence Range, in the pass between that range and Granite Mountain. There is a road from Kelso station, on the Salt Lake Railroad, southward to the springs, which are about 15 miles by road from the station.

163. *Bonanza Well, San Bernardino County* (K-9).—This is a well sunk by the Bonanza King Mining Company about one-fourth mile northeast of the mine hoist. It is known also as the Providence Well. It is on the east side of the Providence Mountains, near the base of the principal peak of the range, about 25 miles northwest of Fenner station, on the Santa Fe Railway. The well was drilled to a depth of 250 feet, the water rising within 100 feet of the surface. It has its source, apparently, in a porous limestone. The water is of fair quality. There is no water on the road from Fenner to this well, and there is only one other watering place in the vicinity, the old Providence Wells (No. 164), at the mill, 2½ miles to the northeast.

It is probable that a considerable water supply could be obtained along the east edge of this range, and that a small area might be irrigated with it by the use of pumping machinery.

There are springs of the same name at No. 180, about 18 miles to the south.

164. *Providence Wells, San Bernardino County* (K-9).—These are old wells near the east edge of Providence Mountains. Their position is marked by the ruins of a little settlement and the old silver mill of the Providence Mining Company (Pl. IV, *A*). Usually there are miners stopping at one of the houses of the old camp. The water from the wells is excellent, and the evidences of former rather extensive cultivation indicate that it must be present in some quantity.

165. *Fenner, San Bernardino County* (K-11).—Fenner (elevation 2,084 feet) is a settlement on the Santa Fe Railway, 269 miles east of Los Angeles. The railway company has drilled a well 800 feet deep at the station and installed a large pumping plant. The water is of good quality and the supply is large.

Fenner is the trading and supply point for the Providence Mountain and adjacent mining districts. A road leads from it north-

A. PROVIDENCE WELLS.

B. ARTESIAN WELL AT BOX S RANCH.

westward to the camp of the Bonanza Mining Company. This road, which may be seen from the station, crosses the desert in a straight line directly toward the prominent Providence Range. About 12 miles from the railway an obscure road branches from it toward the north, going past the east spur of the range. It leads up Black Canyon to Government Holes (No. 145). Near the head of Black Canyon, about 26 miles north of Fenner, on the east side of the road, can be seen the shaft houses of the Out West Gold Mining Company and the road to them. A well-defined trail leads from the shafts eastward across the ridge about a quarter of a mile, to the mining company's camp. There is no water on the main road between Fenner and Government Holes.

166. *Goffs, San Bernardino County* (K-11).—Goffs (Blake postoffice) is a station on the Santa Fe Railway 279 miles east of Los Angeles. It is the junction point from which a line runs northward to Ivanpah, crossing the Salt Lake Railroad at Leastalk. The railway company has drilled a well at Goffs and has installed a pumping plant, from which water may be obtained by the traveler. A good wagon road leads from Goffs northward along the railway. Water may be obtained on this road at Vontreger Springs, about 9 miles north of Goffs.

167. *Ibis, San Bernardino County* (K-12).—Ibis is a station on the Santa Fe Railway about 296 miles from Los Angeles, just east of the summit that the railway crosses before descending to Needles. A wagon road leads northward from the station to Searchlight, and to Eldorado, Callville, and other points on Colorado River in Nevada. The railway company has drilled a well here 300 feet deep and installed a pumping plant. The water is found in cemented gravel and is of excellent quality. Ibis is merely a siding and watering station, and those who need supplies must procure them at Needles.

168. *Klinefelter, San Bernardino County* (K-12).—Klinefelter (elevation 1,445 feet, according to the Santa Fe Railway) is a station on the Santa Fe 299 miles east of Los Angeles. The railway company has installed a large pumping plant here to supply its locomotives. The water is taken from large springs that rise in the deep gravels of the Sacramento Wash. This station is the main source of supply for miners prospecting in the Sacramento Mountains, and travelers can always find water here.

169. *Needles, San Bernardino County* (K-12).—Needles (elevation 491 feet, according to the Santa Fe Railway) is in the valley of Colorado River. This city is the principal supply point for miners and prospectors in the eastern end of the Mohave Desert. The railway company has large machine shops here, and wholesale stores carry an abundance of supplies of all kinds. The water, which is

easily obtained from shallow wells, is of excellent quality, and miners going into the mountains to the north and west are advised to start from Needles with an ample supply, as there is very little to be found within a radius of 20 miles or more except along the railway and the river.

170. *Victorville, San Bernardino County* (L-4).—Victorville is on the main line of the Santa Fe Railway and is the starting point for the most important county roads running east and west along the north base of the San Gabriel and San Bernardino mountains. Mohave River, which flows through the town, is crossed here by means of a bridge, but at other points above and below it must be forded. Ordinarily this is a simple matter, but occasionally, in fall and winter, when travel on the desert is at its maximum, heavy storms in the mountains so increase the flow in the river as to render it unfordable.

The railway company has a well and pumping plant at Victorville, and artesian wells have been developed in the vicinity, so that there is always an abundance of water to be had here. The town is also an outfitting point where teams and supplies of all kinds may be procured.

171. *Colony Well, San Bernardino County* (L-4).—This well is about 9 miles east of Victorville and about 4½ miles north of the county road that runs southeastward from the town. It was dug to supply an agricultural settlement that has recently been established in the desert. The well is about 50 feet deep and yields a limited supply of water of poor quality.

172. *Spring (no name), San Bernardino County* (L-4).—This is a spring on the south side of a western spur of Granite Mountain, about 14 miles northeast of Victorville, on the main road from Victorville to Daggett. The water is good and the place is well marked by débris left by numerous camping parties. This spring furnishes the only water to be obtained on this road between Victorville and Daggett. The main trend of Granite Mountain is north and south, but at the north end a cross ridge runs east and west. This spring is along the south edge of the western extension of this ridge.

173. *Ord Spring, San Bernardino County* (L-5).—This spring is located at the western edge of Ord Mountain, on the road that leads southward from Daggett between Ord and Granite mountains. It is an old camping place and is readily found. A road runs southward from it along the east side of Granite Mountain to the county road at Dead Man's Point, and another connects with the county road from Victorville to Daggett. The water is of good quality.

174. *Le Conte Springs, San Bernardino County* (L-5).—These springs are at the east end of Ord Mountain, about 35 miles east of Victorville and 22 miles southwest of Newberry, on the road that con-

nects these two points. The road is well traveled and the springs are plainly marked by the rubbish left by campers.

175. *Willow Springs, San Bernardino County* (L-5).—These springs are at the north end of Ord Mountain, about 5 miles in an air line north of Le Conte Springs, and about 15 miles south-southeast of Daggett. There is no road or trail leading directly to them and they are used only by prospectors who know of their location. The water is of good quality. Travelers from Victorville to Newberry Springs can obtain a supply of water at Le Conte Springs, which are much more easily found.

176. *Kane's Spring, San Bernardino County* (L-6).—There is a spring of good water at the east base of Kane Mountain, about 6½ miles southwest of Troy station and about 9 miles by road southeast of Newberry station, on the Santa Fe Railway. The spring is on the wagon road from Victorville to Newberry by way of Dead Man's Point and Le Conte Springs.

177. *Spring (no name), San Bernardino County* (L-16).—This spring is in the pass between Bessemer Mountain and a western extension of the Bullion Mountains, about 12 miles south of Hector siding, on the Santa Fe Railway, and about 6 miles south of the road from Newberry station to Mean's Well (No. 198). It is not on any main road. The water is slightly brackish, but is used by the miners who are developing the iron deposits in Bessemer Mountain.

178. *Peacock Spring, San Bernardino County* (L-7).—This spring is at the northwest end of the Bullion Mountains, south of a dry lake. It is about 10 miles from Lavic station, on the Santa Fe Railway, by a wagon road that leads southward from Lavic to Mean's Well (No. 198) and the San Bernardino Mountains. No other water is to be had along this road until Mean's Well is reached, 15 or 20 miles farther to the southwest. The position of the spring is marked by the dry lake and by rubbish of the kind usually found at all old desert camping places.

179. *Mascot Spring, San Bernardino County* (L-8).—There is said to be a spring at the base of the lava flow near the northwest edge of Bristol Dry Lake, about 4½ miles south of Bagdad station.

180. *Bonanza Springs, San Bernardino County* (L-10).—There are springs of good water at the south edge of Clipper Mountain, about 6 miles northwest of Danby station, on the Santa Fe Railway. A local road from Danby leads to them. They are used chiefly by prospectors in Clipper Mountain.

Bonanza well and Providence wells lie about 18 miles north of these springs.

181. *Siam, San Bernardino County* (L-10).—This is a pumping station on the Santa Fe Railway about 6 miles southwest of Danby, in a little pass at the north end of Ship Mountain through which the

railway runs. It is the first station east of Cadiz. The wells sunk by the railway company at this point are not deep, but they supply a large amount of excellent water, which is procured from underlying gravels.

182. *Danby, San Bernardino County* (L-10).—Danby (elevation 3,024 feet, according to the Santa Fe Railway) is a settlement on the line of the Santa Fe 253 miles east of Los Angeles. It is a local supply point for miners operating in Old Woman Mountain, Clipper Mountain, Danby Dry Lake, and at other places in the region. The railway company has drilled a well 637 feet deep and installed a good pumping plant, at which travelers can fill their barrels and canteens. The water is of excellent quality. A good road runs from Danby southward on the west side of Old Woman Mountain to the house built of rock salt on Danby Dry Lake, thence southward to Miller's well (No. 216), at the southwest end of the lake. From Miller's Well the road leads to the Maria Mountains, where there are mining settlements, and thence to Ehrenberg, Ariz. This is the only road southward from Danby. In 1908 a well 60 feet deep was sunk by the side of the road at the north end of Danby Lake, about 2 miles northeast of the Salt House. This well is equipped with a windlass and yields excellent water. The water of Miller's Well is not of good quality, but will serve for animals. Water is next found 15 or 20 miles beyond Miller's well at Brown's well (No. 232).

183. *Old Woman Springs, San Bernardino County* (L-11).—There are large springs in the main canyon on the east side of Old Woman Mountain, named, as is the mountain itself, from a granite pinnacle at the crest of the range. There is no regularly traveled route along the east base of this mountain, nearly all of the travel being by way of the Danby road on the west side. There is, however, a dim trail, washed out in many places, from Danby Dry Lake on the south along the base of the mountain to these springs. The water in the springs rises from granite and is pure and sweet. These springs should not be confused with those of the same name (No. 196) about 35 miles east of Victorville.

184. *Sunflower Springs, San Bernardino County* (L-11).—These springs are on the eastern border of a northern extension of Old Woman Mountain, about 12 miles in an air line southeast of Fenner. The springs are in a cove about half a mile up a canyon which intersects the mountain. There are neither roads nor regular trails to them, but they may be found by the cattle paths that lead to them. The water comes from limestone and is of good quality.

185. *Mellen, San Bernardino County* (L-13).—Mellen (elevation 420 feet, according to the Santa Fe Railway) is a station on the Santa Fe, about 9 miles southeast of Needles, near Colorado River. The railway company has sunk a well in the alluvium of the valley

and installed a pumping plant over it. It is the water-supply point for prospectors in the near-by points of the Mohave Mountains to the south and the Sacramento Mountains to the west.

186. *Burcham ranch, San Bernardino County* (M-4).—This is a well-known ranch near the head of Mohave River, in San Bernardino County, about 7 miles in an air line east of Summit station, on the Santa Fe Railway. It is reached by a road from Cajon Pass that runs through Horsethief Canyon and thence down the river. There is a horseback trail from this ranch to the head of the river and another southward into the San Bernardino Mountains. There is always flowing water in the Mohave River at the ranch.

187. *Dead Man's Lake Well, San Bernardino County* (M-5).—Dead Man's Lake is the first dry lake on the county road that leads from Victorville eastward to the Rose mine, in the San Bernardino Mountains. It is about 18 miles east of Victorville, just beyond a granite spur that projects toward the road from a group of mountains to the north. Near the north edge of this dry lake miners are reported to have drilled a 300-foot well, in which the water rises within 150 feet of the surface. The well is not on the road and can not be seen from it, but a dim trail goes northward across the dry lake to it. The next water is at the Box S Ranch, about 6 miles southeast of this point.

188. *Rabbit Springs, San Bernardino County* (M-5).—Rabbit Springs (elevation about 2,900 feet) have for years been a favorite camping place for parties traveling eastward from Victorville along the north flank of the San Bernardino Range. The springs are about 2 miles north of Box S ranch, on the northwest edge of Rabbit Dry Lake, and are marked by a clump of cottonwood trees that can be seen from the low divide 3 miles west. Since artesian water was found at Box S ranch, travelers have generally followed the road that passes it. At the east edge of the dry lake just west of Box S ranch a road turns to the left (northward) from the main road and crosses a saddle in a rocky point just ahead, while the main road passes south of this point. This left-hand road leads to Rabbit Springs. Some freight teams follow it as the distance is a little less to Copper Well (No. 195), Old Woman Springs (No. 196), and Mean's Well (No. 198) than by way of Box S ranch.

The waters of Rabbit Springs are presumably artesian, and derived from the same source as are those of the Box S wells. The supply is sufficient to irrigate a section or more of land.

189. *Box S ranch, San Bernardino County* (M-5).—Box S ranch (Pl. IV, *B*), elevation 2,935 feet according to U. S. Geological Survey), should not be confused with Box S Springs (No. 192), which are about 6 miles southeast of the ranch. The ranch receives its name from the cattle brand of the company that owns it, the brand being a square inclosing the letter S. The ranch is about 24 miles east of

Victorville, on the county road that leads to the mines in the San Bernardino Mountains, and eastward into the desert. Several wells have recently been drilled at the ranch and in its vicinity, some of which yield flowing water, so that an abundant supply is now available. The locality is easily recognized because of the ranch buildings, the first to be seen by the traveler after he leaves Mohave River at Victorville. It is an important point for desert travelers, because the water is the first to be had along this road east of the river. Meals also may be obtained here.

190. *Spring (no name), San Bernardino County* (M-5).—This is a small spring along the north face of the San Bernardino Mountains, almost due south of Dead Man's Point. It supplies miners who are developing copper prospects in the vicinity. Their tent houses may be seen to the south from the county road that extends from Victorville east.

191. *Lucerne Valley Well, San Bernardino County* (M-5).—In the winter of 1905–6 a well was drilled at the Lucerne Valley ranch, which is about one-half mile north of the wagon road from Rabbit Springs to Old Woman Springs (No. 196). The site, like that of Box S ranch, is marked by buildings.

192. *Box S Springs, San Bernardino County* (M-5).—These springs issue at the base of a low alkaline terrace just north of the road that leads from the Box S ranch southeastward to the Rose mine, in the San Bernardino Mountains. A trough stands by the roadside, and the water is conducted to it by an iron pipe. There is a small but constant flow, and the water is sufficiently free from salts for all purposes. Cushenbury Springs (No. 193) are only about 3 miles distant to the southeast, and the Box S ranch is about 6 miles northwest.

193. *Cushenbury Springs, San Bernardino County* (M-5).—Cushenbury Springs are on the county road that runs from Victorville to Gold Mountain, Doble, Holcomb Valley, and the Rose mine, which are all in the San Bernardino Mountains near Bear Lake. The springs are at the base of the San Bernardino Range near the mouth of a canyon at an elevation of 4,042 feet (U. S. Geological Survey) and are 9 or 10 miles southeast of Box S ranch and about 3 miles beyond Box S Springs. They are marked by a clump of tall cottonwood trees, with alfalfa fields to the south and east and a dwelling among the cottonwoods. There is a good corral and a watering trough by the roadside, to which the water is piped. The yield of the springs is from 3 to 4 miner's inches.

194. *Cactus Flat Springs, San Bernardino County* (M-5).—Cactus Flat Springs (elevation about 5,900 feet) are near the northern crest of the San Bernardino Mountains on the fruit ranch of Mr. J. C. Johnson, who has lived here many years and is the postmaster of Cactus Flat. The ranch and springs are about 6 miles southeast of Cush-

enbury Springs, on the county road from Victorville to Gold Mountain, Holcomb Valley, and the Rose mine. The place is very readily found, as the road, which is well graded and well traveled, runs near the orchard, the house, and the corrals. Troughs are built by the side of the road for watering horses. The springs yield sufficient water to irrigate a number of acres of fruit land. A small stock of canned goods and other supplies is kept by the postmaster, so that travelers may replenish a depleted larder here.

195. *Copper Well, San Bernardino County* (M-5).—This is a new well, recently sunk by miners who are at work on some gold and copper prospects at the east end of Lucerne Valley. It is on the road from Box S ranch to Old Woman Springs (No. 196) and is marked by the miners' buildings.

196. *Old Woman Springs, San Bernardino County* (M-6).—These large springs are at the north base of the San Bernardino Mountains, about 12 miles east of Box S Springs, on the north road from Victorville to Dale, at an elevation of 3,186 feet (U. S. Geological Survey). They should not be confused with the other Old Woman Springs (No. 183) about 90 miles farther east. The water is somewhat alkaline, like that at Box S Springs. The site is marked by a group of cottonwood trees, a ranch house, an orchard, and an alfalfa field. The springs are said to yield from 8 to 30 miner's inches, varying with the season. Hay may be purchased and other accommodations may be had at the ranch at these springs.

197. *Rock Corral, San Bernardino County* (M-6).—A well-known spring, marked by an old rock corral, is situated at the north edge of the San Bernardino Range, about 9 miles west of south from Mean's Well (No. 198), at an elevation of 3,600 feet. The water is abundant and good.

198. *Mean's Well, San Bernardino County* (M-6).—The Gold Pin Mining Company has dug a well 26 feet deep at the northwest edge of Mean's Dry Lake. The water rises within 12 feet of the surface. The company has installed a 12-horsepower gasoline engine to pump the water to its mine, which is in the mountains directly north of the lake. The next water on the west is at Old Woman Springs, about 12 miles distant, but there is another well (No. 199) about 6 miles southeast of Mean's Well on the road to Dale.

199. *Wilbur Well, San Bernardino County* (M-6).—This well is about 6 miles southeast of Mean's Well and about 16 miles west of Surprise Spring (No. 200) on the country road from Victorville by way of Mean's Well to Dale. The water is of good quality, and the well is easily found, as it is close by the roadside.

200. *Surprise Spring, San Bernardino County* (M-7).—This spring is on the county road from Victorville to Dale by way of Mean's Well, about 6 miles west of Mesquite Dry Lake, about 16 miles east of

Mean's Well, and about 12 miles north of Mesquite Spring (No. 211). The spring receives its name from the fact that it is in the open desert where one would least expect to find water. It is close to the roadside, and the location is clearly marked by camp débris. The water is of fair quality.

201. *Dead Man's Hole, San Bernardino County* (M-7).—The springs known under this name are on the west side of Mesquite Dry Lake and east of the county road. They are little more than mud holes in the playa deposits around the lake. The water is full of magnesia and soda salts and is very laxative, but can be used by animals.

202. *Spring (no name), San Bernardino County* (M-8).—This is a spring at the northeast side of the Bullion Mountains, near some old mine workings about 4 miles west of Bristol Lake and about 8 miles southwest of Bagdad station, on the Santa Fe Railway. A trail leads from the station to the spring, which is used only by local prospectors.

203. *Spring (no name), San Bernardino County* (M-10).—This spring is on the west side of Old Woman Mountain, on an old road that runs from Dale northward to a point about 9 miles south of Cadiz, where it turns eastward and crosses the road from Danby station to Danby Lake. It is the first road crossed in driving south from the railway at Danby. The spring is about 6 miles east of the Danby road, in the main canyon of the mountain, and is marked by the ruins of a mining camp. A mill stood near the spring at one time. The supply of water is not large, but the quality is excellent.

204. *Springs (no name), San Bernardino County* (M-10).—These are small springs in the southern end of Old Woman Mountain, about 6 miles north of Danby Lake and about 3 miles east of the road from Danby station to the lake. This road crosses a dry wash containing cottonwood trees, and the springs are found by following this wash into the mountains. They are not on a main road and are not particularly well known, but are used by prospectors. The water flows from granite and is of good quality.

205. *West Well (new), San Bernardino County* (M-13).—This well is on the county road from Needles, Cal., to Parker, Ariz., and is about 30 miles south of Needles, 4 miles southwest of the old West Well (No. 206), and 25 miles northwest of Parker. It is close by the roadside, is protected by curbing, and is provided with a pump and a covered watering trough. The supply of water is sufficient for all needs.

206. *West Well (old), San Bernardino County* (M-13).—This well is near the head of the Chemehuevis Wash, on the county road that runs from Needles, Cal., to Parker, Ariz. It is about 40 feet deep and stands in a clump of cottonwood trees. It is protected by curbing and

provided with an iron pump and a good watering trough with cover. The water rises within about 6 feet of the surface and is of excellent quality.

Since this well was dug the county road has been straightened. The main road now diverges from the old road about 3 miles west of this well and continues southward into the next township, where a new well has been dug. The old well is convenient for prospecting parties in the Chemehuevis Wash.

207. *Warren's ranch, San Bernardino County* (N-6).—This well-known ranch is 28 miles northeast of Banning, at the highest point along the road from Banning to Dale, its elevation being 2,500 feet. It is the usual stopping place for all travelers bound from the north end of the Colorado Desert or from San Gorgonio Pass northeastward by way of Morongo Pass. It is a road ranch and provides travelers with meals, hay, grain, and other supplies. The water used flows from large springs and is pumped to the ranch by a gasoline engine.

208. *Warren's Well, San Bernardino County* (N-6).—This well is 10 or 12 miles east of Warren's ranch. It is 150 feet deep, and the water is pumped by a windmill into a cemented reservoir about 18 feet long, 10 feet wide, and 4 feet deep. Fifteen cents is charged for each team watered here. It is 27 miles by road from the well to Twenty-nine Palms Springs (No. 213).

209. *Coyote Holes, San Bernardino County* (N-7).—This watering place, originally of some importance but now fallen into disuse, is about 7 miles east of Morongo Pass, at the junction of the wagon roads from Victorville, on the Santa Fe, and Banning, on the Southern Pacific. It is about 18 miles by road from Coyote Holes eastward to Twenty-nine Palms Springs and about 9 miles west to Warren's Well. Warren's Well and the springs at Warren's ranch now supply travelers with water, so that Coyote Holes are no longer used and have become badly choked with sand. A slight seepage, however, may be found in a canyon about 1 mile south of the road junction.

210. *Quail Springs, San Bernardino County* (N-7).—These springs are at the north edge of the San Bernardino Range, about 6 miles southeast of Coyote Holes. The water is excellent and the supply can no doubt be increased.

211. *Mesquite Spring, San Bernardino County* (N-7).—Mesquite Spring is on the road from Victorville to Dale by way of Mean's Well, about 3 miles south of Mesquite Dry Lake and 7 miles northwest of Twenty-nine Palms Dry Lake. Its site is marked by granite outcrops, a mesquite grove, and the débris of old camps. The water is of good quality and the supply is ample for travelers.

212. *Sulphur Springs, San Bernardino County* (N-8).—These springs are about 2 miles south of Mesquite Springs, on the county

road from Victorville to Dale. The water is abundant, but tastes strongly of sulphur; and as it is but a few miles southward to other and better springs these are rarely used by travelers.

213. *Twenty-nine Palms Springs, San Bernardino County* (N-8).—The Twenty-nine Palms Springs are scattered for a distance of a mile along the southwest edge of Twenty-nine Palms Dry Lake, about 6 miles south of the south end of the Bullion Mountains, on the roads from Victorville and Banning to Dale and 27 miles east of Warren's Well. They receive their name from the clumps of native palms growing about them. An adobe building stands near the camping place. The water at the springs is abundant enough to supply a number of mining camps in the vicinity. There are several shallow wells near the springs, from which water may also be procured.

214. *Dale Pump, San Bernardino County* (N-9).—A pumping plant has recently been installed at the south edge of Dale Dry Lake, in T. 1 N., R. 12 E., the well, however, being just over the township line to the south. This plant supplies water to Dale, a mining settlement about 5 miles farther south. Dale, long known as Virginia Dale, is the post-office and trading center for the prospectors in the mountains around it. The location of this settlement has been changed several times during the last ten years, but with the development of water its present position will probably prove permanent. The well is reported to furnish an abundant supply of water of good quality.

215. *Desert Well, San Bernardino County* (N-11).—This well is reported to have been drilled near the southeast edge of Iron Mountain, about 4 miles southwest of Miller's Well (No. 216). The writer searched for it recently, but was unable to find it, although it is said to be in the SW. ¼ sec. 3, T. 1 S., R. 18 E., San Bernardino meridian. From the abundance of water plants, however, it is evident that water can be procured without much difficulty in that vicinity.

216. *Miller's Well, San Bernardino County* (N-11).—Miller's Well is situated on the southwest edge of Danby Dry Lake, among the gypsum knobs at the east base of Iron Mountain. It is beside the road that runs southeastward from Danby station, on the Santa Fe Railway, to the Maria Mountains. The well is about 35 or 40 miles south-southeast of Danby. Brown's Well (No. 232) is 20 miles southeast. The water is dark colored and very salty, and only thirsty animals will drink it. Travelers, therefore, should carry with them from Danby an ample supply for men and teams. It is reported that there is another well on the southwest side of Iron Mountain, but the writer was unable to find it. There are two other Miller wells (Nos. 299 and 301) in Nevada, but this well is not likely to be confused with them.

217. *Spring, San Bernardino County* (N-12).—There is a spring near the southeast end of the Turtle Mountains, about 15 miles northeast of Brown's Well (No. 232) on the road to the West Well (No. 205). The water is good.

218. *Palm Springs station, Riverside County* (O-6).—Palm Springs is a station on the Southern Pacific Railroad in the upper end of the Colorado Desert. It is supplied with water from wells. This station should not be confused with Palm Springs proper, which lies at the base of San Jacinto Peak, 6 miles due south. (See No. 219.)

219. *Palm Springs, Riverside County* (O-6).—This is an agricultural settlement and health resort in the upper end of the Coachella Valley, about 6 miles south of Palm Springs station on the Southern Pacific Railroad, at an elevation of 455 feet (U. S. Geological Survey). The lands of the settlement are irrigated in part from these rather large springs, and in part from Whitewater River and the near-by canyons of the San Jacinto Mountains. There are a number of springs here, and some of them are thermal and medicinal. The settlement is named from the wild palms which grow in the vicinity. It is one of the most northerly points in the United States at which these plants are found native.

220. *Palmdale, Riverside County* (O-6).—This agricultural settlement, now largely abandoned, is about 2½ miles southeast of Palm Springs, at an elevation of about 450 feet. Its irrigation was accomplished by utilizing a group of springs that give a good supply of water.

221. *Magnesia Spring, Riverside County* (O-6).—This is a spring of effervescing magnesia water in Magnesia Spring Canyon, about 15 miles west of Indio. The mouth of the canyon is about 2 miles southwest of the Indio road, which passes along the south side of Coachella Valley. A dim trail turns to the southwest from this main road at a point about 6 miles west of Indian Well (No. 234) and leads up to the spring.

222. *Stubby Springs, Riverside County* (O-7).—These springs are on a trail from Palm Springs station to what is known locally as the Thousand Palms Canyon. This canyon is at the southwest edge of the San Bernardino Range, about 18 miles north of Indio. The springs were opened by a freighter known locally by the nickname "Stubby," who made the trail into the canyon.

223. *Lost Horse Spring, Riverside County* (O-7).—This is a spring near the summit of the San Bernardino Mountains, about 6 miles east of the Thousand Palms Canyon. A pack trail leads to it. The spring takes its name from a mining company that at one time operated a 2-stamp mill there, using the water from the spring for the purpose.

224. *Piñon Pine Well, Riverside County* (O-8).—This well is about 25 miles northeast of Indio, on the new wagon road to Twenty-nine Palms Springs. The air-line distance is perhaps 15 miles. A mining company has erected a 2-stamp mill here and sunk a well from which a good supply of pure water is derived. The well receives its name from the piñon trees around it.

About 3 miles southeast of this camp, away from the main road or trails, are the Red Tanks, where water collects in a bowl in the granite. The writer has no information as to the permanency of this supply or the quality of the water.

225. *Stirrup Tanks, Riverside County* (O-8).—These tanks or natural rock basins are in the granite of an unnamed range, the one next west of Pinto Mountain. They are on the road from Indio to Twenty-nine Palms Springs, and have not been known to be dry during the last ten years, a period of exceptionally low rainfall in the Southwest. The water is of excellent quality. Travelers may learn the route to them at Indio or Twenty-nine Palms Springs.

226. *Washington Tank, Riverside County* (O-8).—This tank is in the San Bernardino Range, about 16 miles west of Cottonwood Springs (No. 227). The water is said to be of excellent quality and a fair supply may be depended on in ordinary seasons. Travelers will have to make local inquiries in order to find the tank.

227. *Cottonwood Springs, Riverside County* (O-9).—These springs are in Cottonwood Pass, 26 miles northeast from Mecca, on the main road to Dale. They are 14 miles northeast of Shaver Well (No. 241). The springs are readily found, their site being marked by the ruins of a concrete reservoir and by the corral, water troughs, and engine house of the Iron Chief Mining Company. The water, which is of good quality, is usually flowing, but more or less débris often obscures or obstructs the springs during the winter rains, so that the first travelers in the early spring are obliged to clean them out. About 3½ miles east, on a trail on the south slope of Cottonwood Mountains, are many large native palms growing in the canyons, where water is always standing exposed or close to the surface. At the southwest end of the Providence Range, 75 miles northward, are other springs of the same name (No. 162).

228. *Iron Chief Well, Riverside County* (O-9).—This well is in the northeast end of Eagle Mountains. It is reached by a side road from Cottonwood Springs, which lies about 8 miles southwest. The water is good.

229. *Lightfoot or Bowlder Well, Riverside County* (O-10).—About 6 miles west of Palen Dry Lake a well has been sunk by Lightfoot Brothers, who have erected over it a windmill which is visible for a number of miles. This windmill and pump are usually out of order.

230. *Palen Wells, Riverside County* (O-10).—There are two old wells, 14 feet deep, at the southwest edge of Palen Dry Lake, a few miles east of the Lightfoot well. The water is brackish but potable. In 1905 it was reported that Mr. H. R. Adams drilled a new well near the old ones.

231. *Packard Well, Riverside County* (O-11).—The Packard Well is about 21 miles northeast of the Lightfoot Well, in the Palen Mountains. It is near the bottom of a small arroyo and is surrounded by mesquite trees. The well is not covered, so that the water is often contaminated by the bodies of desert animals. A ridge of limestone south of the well serves as a landmark.

232. *Brown's Well, Riverside County* (O-11).—This is a drilled well, 300 feet deep, near the junction of the roads from Mecca and from Danby Lake to Ehrenberg, Ariz. Its location is plainly determinable from the road, as there are two adobe buildings and a corral near it. It is owned by Floyd Brown, who lives there. No charge is made for water.

234. *Indian Well, Riverside County* (P-7).—This well is situated among the sand hills about 6 miles west of Indio, at an elevation of 97 feet (U. S. Geological Survey). It is on the road along the southwest side of the Coachella Valley, connecting Palm Springs with the settlements about Indio, and is just north of a rough spur of the Santa Rosa Range that extends northwestward for some miles into the desert. The well is 30 or 40 feet deep and is an open shaft in which a pump has been placed.

235. *Indio, Riverside County* (P-7).—Indio (15 feet below sea level), the end of a division on the Southern Pacific Railroad, is well known as a health resort and as the shipping point for a thriving agricultural district. The railroad company has wells here and a pumping plant for supplying the settlement and the road. In this vicinity there are also many other pumping plants that supply water of the finest quality in considerable volume for irrigation and other purposes.

236. *Coachella pumping plant, Riverside County* (P-7).—The Southern Pacific Railroad Company has installed a pumping plant at Coachella station, which is between Indio and Mecca. The water comes from the deep gravels that underlie the Coachella Valley. Throughout this valley from Indio to Mecca there has been rapid development since 1900 by the utilization of underground waters. There are now several hundred wells bored, most of them yielding artesian water of the finest quality. Their use is rapidly transforming this part of the desert into a rich agricultural district.

237. *Toro Springs, Riverside County* (P-7).—This group of springs and the one next to be described are two among a number of ciénagas in which the artesian waters under this part of the desert rise to the

surface. Indian settlements are grouped about these watering places, which were formerly of much importance, but are now less valuable because of the numerous artesian wells in the vicinity. Toro is about 9 miles south of Indio, at 111 feet below sea level, on the old wagon road that follows the western edge of the Colorado Desert.

238. *Alamo Bonito Springs, Riverside County* (P-7).—These springs, which are similar to those at Toro, just described, are about 5 miles southwest of Mecca, at 186 feet below sea level (U. S. Geological Survey). The name is Spanish, and signifies "good poplar." Cottonwood trees are abundant in this vicinity.

239. *Agua Dulce, Riverside County* (P-8).—This is a cluster of strong springs of "sweet water," as the Spanish name indicates, on the west side of the Colorado Desert, about 7 miles south of Mecca, on the road from Mecca to Seventeen Palms Springs (No. 254). They lie 183 feet below sea level (U. S. Geological Survey). The springs are due to the up-welling of artesian waters that are imperfectly confined by the clay strata underlying this part of the Colorado Desert. There are a number of springs in the group, and several Indian habitations are scattered around them. The flow is constant, so that water may be obtained here at any time. Originally they were of much importance, but the settlement of this particular region and the boring of artesian wells in the vicinity have lessened the value of the natural springs.

240. *Mecca, Riverside County* (P-8).—Two artesian wells bored at Mecca station by the Southern Pacific Railroad Company were among the first successful wells in the Coachella Valley. They have a strong flow, and besides furnishing a supply for the locomotives and tank cars of the Southern Pacific system, are utilized by some of the settlers in the village.

241. *Shaver Well, Riverside County* (P-8).—This well is about 12 miles northeast of Mecca, on the road to Dale. It is at the upper end of a box canyon, within sight of the road, and is easily found. It is about 30 feet deep, well timbered and protected. There is a rope, bucket, and pulley, so that it is easy to get the water, which is of superior quality. The well is surrounded by mesquite shrubs and palo verde. Three miles southwest of Shaver Well, in a canyon that opens to the south, over a ridge, half a mile south of the county road, is water surrounded by a few burnt palms, and about 2 miles farther to the southeast, up another canyon in a little side glen, is a beautiful clump of palms with a spring of pure water beneath them.

242. *Dos Palmas, Riverside County* (P-8).—Dos Palmas is a well-known stopping place on the old San Bernardino and Yuma road, about 6 miles east of new Salton station, on the Southern Pacific Railroad, near the clearly defined old beach line that stands 40 feet above sea level in the Colorado Desert. The position of the springs

is marked by two large desert palms, which give the name to the place. The springs yield a large quantity of tepid and slightly salty but drinkable water, the first to be found on this old road southeast of Mecca, which is about 16 miles distant. The next water to the southeast is at Frinks Springs (No. 258), 12 miles away. Since the building of the Southern Pacific Railroad the old wagon road is only occasionally used.

The Orocopia Mining Company has established a pumping plant at the springs, by means of which the water is pumped to its mines, 12 miles farther north.

243. *Canyon Springs, Riverside County* (P-9).—These springs, which yield a small supply of poor water, are in a side canyon north of the road that runs from Mecca via Salton to Palen Dry Lake. South of the springs the road branches, one fork crossing the pass in the Chuckwalla Mountains to the north and the other fork turning southeastward across the divide to the Ironwood Mountains. Water is again found on the northern road, near the southwest edge of Palen Dry Lake, about 25 miles away.

244. *Mill Camp, Riverside County* (P-10).—This is a mining camp about 30 miles east of Salton, on the Ehrenberg road. There are buildings at the springs, which furnish plenty of good water.

245. *Aztec Well, Riverside County* (P-10).—This well is about 9 miles east of Mill Camp on the road to Ehrenberg. There is an abundance of good water.

246. *Granite Tanks, Riverside County* (P-10).—These tanks or natural basins in the granite are at the northeastern edge of the Chuckwalla Mountains. The water, which is of fine quality, rises at the foot of a granite outcrop in a little ciénaga about 25 feet across, and flows over the surface for a short distance before it sinks into the sand. More water could probably be procured here by development. The tanks are on the road from Mecca station to the Ironwood Mountains, about 6 miles southwest of Long Tanks, another watering place of similar character, and about 10 miles south of the Palen Wells (No. 230). Lightfoot or Bowlder Well (No. 229) is about 14 miles northward by road. The first water to be obtained to the east is at McCoy Spring (No. 249), in the Ironwood Mountains, 25 miles distant.

247. *Corn Springs, Riverside County* (P-10).—These springs are situated on the east side of the Chuckwalla Mountains, about 6 miles south of Granite Tanks. The water, which amounts to 8 or 10 miner's inches, rises in a local ciénaga. It is probable that careful development would increase the flow and furnish water enough for the irrigation of a number of acres.

248. *Chuckwalla Spring, Riverside County* (P-10).—This spring is on the south road from Mecca to Palo Verde, near the southwest edge of the Chuckwalla Mountains, in a pass that separates this range and the Chocolate Mountains. The water is of excellent quality and is fairly abundant.

249. *McCoy Spring, Riverside County* (P-11).—This spring is on the west edge of the McCoy or Ironwood Mountains, about 25 miles east of Granite Tanks, on the road from Mecca to Ehrenberg. The water is excellent, but the supply is small, the springs yielding only about 4 barrels a day.

250. *Springs (no name), Riverside County* (P-12).—These springs are at the east edge and near the north end of the Palo Verde Mountains, about 7 miles northwest of the town of Palo Verde, and are used by stockmen.

251. *Spring (no name), Riverside County* (P-12).—There is reported to be a good spring on the old Ehrenberg road to Mecca, about 5 miles northwest of Colorado River, but the writer has no further information concerning it.

252. *Borego Spring, San Diego County* (Q-7).—Borego Spring is on the west bank of the broad Borego Wash, at an elevation of 452 feet (U. S. Geological Survey). Its distance by wagon road from Julian is about 33 miles. The water of this spring, although somewhat alkaline, is entirely usable. Mesquite trees grow near the spring and in the valley, and salt grass, willow, and rushes are abundant. An old cabin stands on the bank about 50 feet from the spring and serves to mark its position.

From Borego Spring the wagon road runs down the Borego Wash about 2½ miles to its junction with the San Felipe Wash, which comes in from the southwest. Just beyond the junction of the two washes the road forks, one branch continuing down the San Felipe, the other turning to the left and crossing the mesa and the clay hills toward Seventeen Palms Springs (No. 254). Neither road is much used, and after rains both are dim and difficult to follow.

253. *Clark Well, San Diego County* (Q-7).—This well is about three-fourths of a mile north of the northeast end of Clark Dry Lake, at an elevation of 555 feet (U. S. Geological Survey). Trails lead to it from Rock House Canyon and from Coyote Creek valley, and a little-used wagon road connects near Borego Spring with the road from Seventeen Palms Springs to Julian. The well can be easily found from its position north of the dry lake. The water is good.

254. *Seventeen Palms Springs, San Diego County* (Q-7).—Seventeen Palms Springs lie at an elevation of 410 feet (U. S. Geological Survey), near the junction of three washes in the clay hills, south of the Santa Rosa Mountains. At present only eight or nine palm trees stand near them, the remainder of the seventeen, from which the

springs were named, having been destroyed by fire. The springs are about 12 miles by wagon road east from Borego Spring, or 45 miles from Julian, but the road is little used, is dim, and may be difficult to follow, particularly after the winter rains. Broken clay hills and deep washes surround the springs. Grass and wood in small quantities may be found near them. When they are kept open the water is fairly good, but it becomes bitter and bad by neglect and disuse. The soil is impregnated with alkaline salts.

255. *Soda Springs, Imperial County* (Q-8).—Soda Springs are located about 15 miles southeast of Fish Springs (No. 256), on the road from Mecca down the west side of the Colorado Desert. The water is so salty as to be scarcely potable and near by are other springs whose water is entirely undrinkable. Soda Springs are at the base of a low barren knoll, one-half or three-fourths of a mile south of Clay Point, marked by a government bench mark, around which the road turns on the way from Mecca to Seventeen Palms Springs. The road from Clay Point south toward Harper Well (No. 264) is very little traveled and is difficult to find.

256. *Fish Springs, Imperial County* (Q-8).—Fish Springs (230 feet below sea level), now (1908) submerged to a depth of about 25 feet beneath Salton sea, are a group of strong natural springs whose aggregate yield is several miner's inches. The waters are tepid and slightly saline, but of sufficiently good quality to be used by men or animals without injurious effects. Before their submergence these springs were especially important to travelers because they are at the southernmost point at which water of fair quality can be procured in abundance along the west side of the desert until Harper (Mesquite) Well is reached. They will emerge again as the lake shrinks by evaporation, and when the lake water has become too saline for use they will again become important. Their position is indicated by a prominent rocky point which stands out in the desert about 1 mile east of the base of the Santa Rosa Mountains, and which is conspicuous not only because of its position but because of the distinct water line that encircles it 10 or 15 feet below its summit. This point is about 2 miles northeast of the springs.

257. *Figtree John's Springs, Riverside County* (Q-8).—This small group of springs is about 12 miles south of Mecca station, and about 3 miles southeast of Agua Dulce, at 197 feet below sea level (U. S. Geological Survey). About the springs are clustered the huts of the family of Figtree John, one of the Coahuila Indians. The water is tepid but is abundant and of excellent quality. The position of the springs is marked by a number of large fig trees. They are about 1 mile east of north of a rocky outlier of the Santa Rosa Mountains, which also serves as a landmark for the location of Fish Springs, about 3 miles farther south. Figtree John's Springs

were submerged during the winter of 1906–7 by the rising waters of Salton Sea, but will reappear as the water subsides.

258. *Frinks Springs, Imperial County* (Q-9).—These springs are about 6 miles northwest of Frinks station, on the Southern Pacific Railroad. They are on one of the old wagon roads from San Bernardino to Yuma, near the old beach line that stands about 40 feet above sea level in the Colorado Desert. The water is of good quality and in fair quantity.

259. *Spring (no name), Riverside County* (Q-11).—This spring is at the south base of a western outlier of the Palo Verde Mountains, about 6 miles northeast of the Chuckwalla settlement, on the road thence to Ehrenberg, Ariz. The spring is near the road, has long been known and used, and is readily found. The quality of the water is good and the supply is fair.

260. *Mule Springs, Riverside County* (Q-11).—These springs are in the main pass on the west side of the Palo Verde Mountains, on the road from Mecca to Palo Verde, by way of Chuckwalla, and about 8 miles northeast of the Chuckwalla settlement, which itself lies at the east base of the Chuckwalla Mountains. The position of the springs is marked by a grove of timber. The water is good and the supply abundant.

261. *Vallecito Springs, San Diego County* (S-7).—Vallecito Springs are located in the valley of Vallecito Creek, about 33 miles east of Julian, on the wagon road to Carrizo station (No. 270), at an elevation of about 1,600 feet. The old adobe stage station, in use when this road was a part of one of the transcontinental stage routes, still stands and is in fairly good condition. A watering trough stands near the building, and there are mesquite and cottonwood trees in the vicinity. The quality of the water is fair.

262. *Hanna Well, San Diego County* (R-7).—This well is at the base of the north slope of Black or Fish Creek Mountain, 15 or 18 miles southeast of Borego Spring, and 10 or 12 miles southwest of Harper (or Mesquite) Well (No. 264). It is not on a main road, but is near the mouth of a canyon heading in a pass that leads to the valley of Carrizo Creek. The water is good.

263. *McCain Springs, Imperial County* (R-8).—McCain Springs are about 5 miles somewhat east of south of Clay Point, mentioned in the description of Soda Springs (No. 255). They are in the center of a broad wash, locally called the Arroyo Grande, and are marked by three large sand dunes from a quarter to half a mile southwest. The surrounding country is traversed by numerous gulches from 6 to 20 feet in depth and often difficult to cross. The springs, which are well below sea level, have built up a small mound in the bed of the wash. The water appears to be charged with carbonic acid gas and is fairly palatable.

In March, 1901, excellent water was found by digging a hole in the sand near the right bank of the wash, about 430 feet upstream from the springs. Firewood is scarce in the vicinity, but grass for stock may be found some distance away. These springs are about 9 miles southeast from Seventeen Palms Springs.

264. *Harper (or Mesquite) Well, Imperial County* (R-8).—At the junction of Carrizo and San Felipe creeks an attempt was made a few years ago to develop oil. No oil was found, but at a depth of about 300 feet a flow of good water was obtained. The site of the well is plainly marked by the derrick, which can be seen for a long distance across the desert. There is an abundance of mesquite timber in the vicinity.

265. *Kane Spring, Imperial County* (R-8).—This spring is 6 miles east of Harper Well, on top of a low knoll. It is surrounded by cane, salt grass, and arrow weed. The water is full of soda and is very poor, being hardly fit for use.

266. *Agua Caliente Springs, San Diego County* (S-7).—About $3\frac{3}{4}$ miles eastward from Vallecito Springs and about three-fourths of a mile southeast of the main wagon road between Julian and Carrizo station there are several springs in a natural amphitheater comprising an area of about 50 acres. The water is tepid and is impregnated with sulphur, but is not unpleasant to the taste. The combined flow of the springs makes a rather large stream. Grass and wood are scarce.

267. *Mountain Palm Springs, San Diego County* (S-7).—These springs are at the foot of a high, broken rocky ridge and are several miles south of the main wagon road across the Sierra Madre, but can be easily reached by a side road that was made a few years ago. The water is cool and fairly good. Wild palms and other vegetation make the vicinity inviting.

268. *Palm Springs, San Diego County* (S-7).—There are several Palm Springs in San Diego County, but those here referred to are about 9 miles east of Vallecito Springs, just north of the line between sections 25 and 36. The palms that gave the springs their name were destroyed long ago, but there are several mesquite trees near by. The springs are situated under a clay bank, and digging is sometimes necessary in order to obtain water. The water has a temperature of about 60° and is somewhat sulphurous.

269. *Mason ranch, San Diego County* (S-7).—Mason ranch is on the road from Carrizo Creek to Sentenac and Agua Caliente (Warner's ranch). This is the principal road through this part of the desert, and may be easily followed and identified. At the ranch, which will be recognized at once by travelers over the road, an excellent supply of water has been developed.

270. *Carrizo station, San Diego County* (S-8).—Carrizo station (elevation, 450 feet) is near the left bank of Carrizo Creek wash, about 9 miles east of Palm Springs, on the main wagon road from Julian to the Imperial Valley. There are a number of springs near the station, and two of them furnish fairly good water. There is also a rather large tule swamp around the station, from which a strong stream of alkaline water flows. Rough clay hills of late Tertiary age, showing typical badland erosional forms, are prominent features of this region. Carrizo was originally a stage station on one of the old overland lines, but the adobe buildings are now in a dilapidated condition, their ruin having been completed by the earthquake of February, 1892.

271. *Coyote Well, Imperial County* (S-8).—Coyote well is about 375 feet above sea level, on the main wagon road from Mountain Springs (No. 274) to Silsbee, the southernmost of the wagon roads that cross the Sierra Madre from the Imperial Valley to San Diego. The old Coyote well was a mere pit curbed up with planks. A new well, standing about 100 feet from the old one, was fitted up with a pump, but this has been broken recently. The water is rather alkaline, but improves after the well has been used for some time.

272. *Yuha Springs, Imperial County* (T-8).—Yuha Springs are located in a wash near the corner of sections 5, 6, 7, and 8, about 5 miles southeast of Coyote well and a mile southwest of the derrick at the Yuha oil well. The regular wagon road from Campo to Silsbee crosses the desert about 2 miles north of the springs. The water is impregnated with alkaline matter, but when used continuously is not unpleasant or harmful. In 1905 there was a trough and pump at the springs.

273. *Sunset Springs, Imperial County* (S-10).—These springs, which have long been known, are about 13 miles south of east from Brawley, below the old beach which is so prominent a feature about the borders of the Colorado Desert. It is reported that the paths of animals using the springs led to their discovery. They are of less importance now than before the reclamation of so large a part of the Imperial Valley by the introduction of Colorado River waters.

274. *Mountain Springs, San Diego County* (T-7).—Mountain Springs are about 9 miles by wagon road from Jacumba Springs (No. 275) and 33 miles from Campo, at an elevation of about 2,500 feet. Forty years ago there was a stage station here on the Butterfield stage line that ran from San Diego to Yuma. The ruins of the old stone corral and buildings are still visible. The water issues from the side of a rocky ravine and a portion of it is carried in an inch pipe about 200 feet long to a trough beside the road. Its quality is excellent.

From Mountain Springs the wagon road leading to the desert runs through a rocky gorge in which water can be found a portion of the year. From the mouth of the gorge the surface slopes gently eastward to Coyote Well, 12 miles from Mountain Springs and 45 miles from Campo.

275. *Jacumba Springs, San Diego County* (T-7).—Jacumba Springs are about 24 miles east of Campo, near the quarter-section corner between sections 7 and 8, T. 18 S., R. 8 E., and about ¼ mile north of Monument No. 233 of the boundary line between the United States and Mexico, at an elevation of about 2,825 feet. They are on the west side of a long, open valley whose outlet is to the northeast, through a deep, narrow gorge. The greater part of this valley, which is the head of the Carrizo Creek drainage system, is in Mexico. The springs include one of cold water and several that yield waters with temperatures ranging from 86° to 98° F. These thermal waters are regarded as medicinal, and a bath house and other accommodations are provided for travelers.

NEVADA.

276. *Palmetto, Esmeralda County* (A-3).—This is one of the oldest settlements in the northern portion of the Palmetto Range, and is an outfitting point for prospectors in that region. It is reached by a road from Alvord station, on the Southern Pacific Railroad, by way of Deep Springs and Oasis, and is well supplied with water from both wells and springs.

277. *Indian Spring, Esmeralda County* (A-3).—This spring is about 6 miles east of the Palmetto Mountains and about the same distance northwest of Barrel Springs (No. 278). Parties prospecting in the region can obtain full directions for reaching it at Palmetto or at Lida.

278. *Barrel Springs, Esmeralda County* (A-3).—These springs are in the eastern edge of the Palmetto Mountains, about 1 mile northeast of Lida and about 5 miles southeast of Indian Spring. As the country is comparatively well settled, directions for finding the springs can be had at Lida or at Palmetto.

279. *Gold Mountain, Esmeralda County* (A-4).—There is a well at this point, 1 mile east of Tokop and 20 miles southeast of Lida, that yields a small supply of good water. There is another well 1¼ miles northeast of this one, across two small ridges. The water is good.

280. *Old Camp, Esmeralda County* (B-4).—This is a small spring near the summit of Gold Mountain, having a fair supply of good water.

281. *Willow Spring, Esmeralda County* (B-4).—This is a small spring on the east side of Gold Mountain, near the summit, 1¼ miles southeast of Old Camp. The supply is scanty, but the water is good. There is also a spring of the same name (No. 287) about 20 miles southeast, in the Grapevine Range.

282. *Thorp Mill, Nye County* (B-5).—This site is marked by an old stamp mill. It was originally a stage station and post-office on the road from Goldfield to Bullfrog, but the station has been abandoned and the post-office moved to Bonnie Claire station, 2½ miles farther north. The road between Goldfield and Bullfrog passes the mill. A well and a spring supply an abundance of good water here.

283. *Bonnie Claire station, Nye County* (B-5).—This station is at the northwest edge of Sarcobatus Flat, about 35 miles south of Goldfield, on the stage road from Goldfield to Bullfrog, at an elevation of 3,973 feet (U. S. Geological Survey). Several wells that have been sunk 12 feet into the playa deposits yield a good supply of slightly brackish water. This station has taken the place of the old Thorp Mill and Summerville stations, about 2 miles farther south and now abandoned. Thorp post-office, originally located at Thorp Mill, has been moved to Bonnie Claire station.

284. *Tonopah Well, Nye County* (B-5).—This well is about 7½ miles southeast of Bonnie Claire station, at the southwest edge of Sarcobatus Flat. A well about 20 feet deep has been sunk in the playa deposits, but the water is poor.

285. *Seattle Well, Nye County* (B-5).—This well is on the road from Goldfield to Bullfrog, about 1¼ miles south of the Tonopah Well and about 1½ miles southwest of a dry lake bed. It is about 20 feet deep, but has no pump or windlass. The water is abundant and good.

286. *Farmer station, Nye County* (B-5).—Farmer station is a halfway house between Goldfield and Bullfrog, on the old private road of the automobile company. It is on the east side of Sarcobatus Flat, about 5 miles east of Bonnie Claire station. Private conveyances use the road by way of Bonnie Claire station, as they can find no water on the old automobile road until they reach the head of Amargosa River.

287. *Willow Spring, Nye County* (C-4).—This spring is about 4 miles a little east of north of the highest peak in the Grapevine Range, known as Grapevine Peak. It is on the north side of a high spur at the end of a wood road. There is another Willow Spring (No. 281) about 20 miles northwest, in Gold Mountain.

288. *Brier Spring, Nye County* (C-5).—This spring is about 3 miles south of east of Wahguyhe Peak, on the northwest slope of a big spur of the Grapevine Range, about 1 mile northwest of Mexican Camp No. 289, and 1 mile north of the Alkali Spring mentioned

below. There is a plentiful supply of good water. There are also springs in the first canyon due east of Wahguyhe Peak, and about 2 miles a little south of east of the peak. The water is abundant and good.

289. *Mexican Camp and Alkali Spring, Nye County* (C-5).—This is a wood camp in the Grapevine Range in the first canyon south of Wahguyhe Peak that drains into the Amargosa Desert, at the end of the wagon road about 1½ miles east of the divide. It is about 13 miles north of west of Bullfrog, and 2½ miles northeast of Nevada-California boundary post No. 91. The spring is small, with very little water. There is a trail from Mexican Camp to Death Valley by way of Titus Canyon, and on this trail about 1¾ miles southwest of the camp, one-fourth mile west of the divide on the north side of the trail, there is a small spring called Alkali Spring by some. The supply of water is small and its quality is poor.

290. *McDonald Spring, Nye County* (C-5).—This spring is on the east slope of the Grapevine Range, 10 miles a little north of west of Bullfrog, about 2½ miles north of Cave Rock Spring (No. 291), and 1 mile south of a wood road on the south side of a small butte. The supply of water is small.

291. *Cave Rock Spring, Nye County* (C-5).—This spring is on the east slope of the Grapevine Range, about 10 miles a little south of west of Bullfrog, and 2 miles south of east of Nevada-California boundary post No. 92. It is well up the slope above the wash and accessible to wagons. The flow is about 4 barrels per day.

292. *Currie Wells, Nye County* (C-5).—This watering place is 10 miles northwest of Bullfrog, on the road from Goldfield, at an elevation of 4,401 feet (U. S. Geological Survey). Water is obtained from three wells, 10, 12, and 14 feet deep, yielding about 200 barrels of excellent water daily. There is a stage station here, at which meals and forage for animals can be obtained.

293. *Mud Spring, Nye County* (C-5).—These springs are about 10 miles north of Bullfrog and about 4 miles northeast of Currie Wells, on the south edge of Sarcobatus Flat. They have been extensively used by freighters and their location is clearly marked by camp débris. There is a fair supply of good water.

294. *Oasis Valley, Nye County* (C-6).—This is the name given to the valley in which Amargosa River rises. In it there are nearly 100 springs, which constitute the source of the river. These springs are scattered along the valley for about 6 miles and yield thermal as well as cold waters. Among them are the Oasis Springs, from which water is piped to the town of Bullfrog. This valley should not be confused with Oasis, a settlement in the southeastern corner of Mono County, Cal.

295. *Topopah Spring, Nye County* (C-7).—This is also called Black Rock Spring. It is about 15 miles northwest of Cane Spring (No. 298), high up on the south slope of Shoshone Mountain, on the east side of a basin bounded on the west by low "calico" hills. The supply of water is very meager.

296. *Railroad Tank, Nye County* (C-8).—This tank, or natural basin, is in the open valley about 20 miles due south of Oak Springs Butte, one-half mile west of White Mud Flat (a dry lake), and 13 miles north from Cane Spring (No. 298). The water is very alkaline, and the tank is usually dry in August.

297. *Rose's Well, Nye County* (D-6).—This well is near a station on the Las Vegas and Tonopah Railroad, being about half a mile west of the railroad, on the old stage road from Fairbanks Ranch to Bullfrog. The well is 210 feet deep and yields about 100 barrels per day of good water.

298. *Cane Spring, Nye County* (D-8).—This spring is on the old emigrant road from Salt Lake to Los Angeles, about 13 miles south of Railroad Tank, about 45 miles south of east from Bullfrog, and 25 miles northeast of Fairbanks Ranch. It is 30 miles by road northwest of Indian Springs station, on the Las Vegas and Tonopah Railroad. The water is good and the supply is about 25 barrels per day.

299. *Miller Well, No. 1, Nye County* (E-6).—This is a well dug by Mr. Miller, on the stage and automobile road from Las Vegas to Bullfrog. It is about 8 miles northwest of the Fairbanks Ranch, at an elevation of 2,555 feet (U. S. Geological Survey). The well is about 200 feet deep, and will supply 200 barrels per day. There is no rope, as the well has not been used since 1905.

300. *Fairbanks Ranch, Nye County* (E-7).—This is a well-known ranch and stopping place for travelers on the roads leading from Barnwell to Ivanpah, Cal., and from Roach and Jean, Nev., northward by way of Manse. The ranch is near the north end of Ash Meadows, at the southeastern edge of what is known as the Amargosa Desert. It has been occupied and cultivated for a number of years, and is supplied with an abundance of water from springs that suffice to irrigate a large tract. Both grain and provisions may be obtained here by travelers.

Roads lead from Fairbanks Ranch southeastward to Pahrump (35 miles away) and to Manse (40 miles away). There are no regular watering places between Fairbanks Ranch and Pahrump. Other roads toward the northeast and north connect with the main Las Vegas-Bullfrog road at Miller Well No. 2, and still other roads lead westward to Furnace Creek and the north end of Death Valley. Specific details as to all these roads can be had at the ranch.

301. *Miller Well No. 2, Nye County* (E-7).—This well, now abandoned, was dug by Mr. Miller on the stage and automobile road from

Las Vegas to Bullfrog and stands at an elevation of 2,490 feet. (U. S. Geological Survey.) It is about 6 miles northeast of Fairbanks ranch and about the same distance southwest of Amargosa station, on the Las Vegas and Tonopah Railroad. There is a building at the well, and until recently water has been sold to travelers. The well is about 70 feet deep and can supply 100 barrels per day. The water is brackish, and there is no rope at the well, which has not been in use since 1905.

302. *Johnnie, Nye County* (E-8).—This mining settlement has come into existence since 1902. It is about 18 miles west of north from Pahrump and about 12 miles southeast of Miller Well No. 2. Water is piped to the town from Horseshutem Spring, about 4 miles to the east.

303. *Kevichup Spring, Nye County* (E-8).—This spring is near the Johnnie mine, 5 or 6 miles northeast of the town of Johnnie. The water is used for the mining camp, and is said to be of excellent quality.

304. *Hornet Springs, Lincoln County* (E-9).—These springs are on the northeast slope of Spring Mountain, about 7 miles south of Elderberry and about 20 miles northeast of Manse, on a road from Manse to Indian Springs (No. 305). They yield a large supply of water of excellent quality.

305. *Indian Springs, Lincoln County* (E-9).—These springs are about 20 miles northwest of Corn Creek Spring, 35 miles east of Miller Well No. 2, and 45 miles from Las Vegas. They are more than 5 feet deep and yield an abundant supply of water, which issues from limestone. This is one of the important camping places on the stage and automobile road from Las Vegas to Bullfrog.

306. *Corn Creek Spring, Lincoln County* (E-10).—This spring forms another stopping place on the road from Las Vegas to Bullfrog. It yields from 1 to 2 miner's inches of excellent water.

307. *Pahrump, Nye County* (F-8).—Pahrump, one of the oldest settlements in the southern portion of Nevada, is about 7 miles northwest of Manse, on the road to Fairbanks ranch. It is a large ranch, in whose cultivation a number of Indians are employed. Here orchards, vineyards, and extensive fields of alfalfa flourish, and the water used in irrigation is supplied by a number of large, deep-seated warm springs, similar to those at Manse. Travelers can obtain hay and grain here.

308. *Manse Springs, Nye County* (F-8).—The springs at Manse have been known for years to travelers going northward from points in southern Nevada, and the place has long been the principal stopping point along this route. By the use of the water which the springs yield, this portion of the desert has been converted into a veritable oasis, and the 500 or 600 acres of alfalfa, orchards, and

vineyards show the capabilities of the desert soil when water can be applied to it in sufficient quantity.

The springs are over 20 feet in diameter and from 5 to 6 feet deep. The bottom is of white sand, and warm water boils up through this in large volume. These important springs and those of similar character at Saratoga Springs, Resting Springs, and Indian Springs, all occur along a line that runs nearly northeast and southwest. All of them are remarkable for the volume and purity of the water they yield.

311. *Mountain Spring, Lincoln County* (F-9).—This spring is about 4 miles, air line, southwest of Wilson's ranch, and on the other (the western) slope of Spring Mountain. It is about 8 miles northwest of Crystal Springs (No. 316), and is but little below the highest point on the road from Las Vegas westward to the Pahrump Valley. It is close by the roadside and its position is well marked. The supply of water is ample.

There are many springs in Spring Mountain, many of which are well known locally and may be reached by roads or trails from Pahrump, Manse, Las Vegas, and points on the San Pedro, Los Angeles and Salt Lake, and Las Vegas and Tonopah railroads.

312. *Tule Springs, Lincoln County* (F-10).—These springs are about 12 miles northwest of Las Vegas, on the road from Las Vegas to Bullfrog. The waters rise along the edge of a dry lake in the northwestern extension of Las Vegas Valley. They are the first springs to be found along this road beyond Las Vegas.

313. *Vegas Springs, Lincoln County* (F-10).—These are warm springs about 2 miles west of the city of Las Vegas. They yield a supply that is used locally for irrigation. Frémont stopped here May 3, 1844, and speaks of the waters as "two narrow streams of clear water, 4 or 5 feet deep, with a quick current, from two singularly large springs." The water has a pleasant taste, but is rather too warm to be agreeable, the temperatures being respectively 71° and 73° in the two springs.

314. *Mesquite Springs, Lincoln County* (F-11).—These springs are about 10 miles southeast of Las Vegas, on the south road leading thence to Callville. The water supply is reported to be good, and the position of the springs is clearly marked by camp rubbish. Mesquite Wells (No. 320) are in Mesquite Dry Lake, about 35 miles southwest, on the western edge of the State.

315. *Stump Spring, Lincoln County* (G-9).—This spring is about halfway between Sandy and Manse, on the old stage road from Ivanpah to Manse. It is protected by curbing, and the water must be drawn by a bucket. Roads from Stump Spring lead westward to Resting Springs, and eastward to Las Vegas, both by way of Crystal Springs (No. 316) and by way of Wilson's ranch (No. 317).

316. *Crystal Springs, Lincoln County* (G-9).—These springs are in a pass between two ranges that have only local names, about 8 miles southeast of Wilson's ranch. They are plainly marked, as they have been used for many years by the settlers.

317. *Wilson's Spring, Lincoln County* (G-10).—This spring is on the well-known Wilson ranch, about 20 miles south of west from Las Vegas, on the road from Las Vegas to Stump Spring. The water is used for irrigating the ranch.

318. *Cottonwood Springs, Lincoln County* (G-10).—These springs are 4 miles southeast of Wilson's ranch and about 18 or 20 miles southwest of Las Vegas, on the old wagon road from Las Vegas to Good Springs or Jean station. The water is good and its amount great enough to irrigate a small ranch.

319. *Sandy, Lincoln County* (H-9).—Sandy, a mining settlement and post-office, is on the old stage road from Ivanpah to Manse. It is about 1 mile north of Mesquite Dry Lake and about 16 miles west of Good Springs or Jean station, on the Salt Lake Railroad. Water is to be had at several near-by points east and south, but on the road running northward the nearest water is found at Stump Spring, about 18 miles away. There are stores in the settlement, where supplies may be obtained.

320. *Mesquite Wells, Lincoln County* (H-9).—These wells are in a clump of mesquite trees in Mesquite Dry Lake, about 3 miles south of Sandy post-office, on the stage road from Ivanpah to Manse. They are protected by curbing, and the water stands so near to the surface that it is easily drawn up in a bucket. The quantity is sufficient and the quality fair.

321. *New England Springs, Lincoln County* (H-9).—These springs are between Jean and Sandy, on the road connecting the two points. At the springs a branch road turns northward to Crystal Springs and Wilson's. The flow of the springs is estimated at 1 or 2 miner's inches.

322. *Good Springs, Lincoln County* (H-10).—These springs are on the road to Sandy post-office, about 6 miles west of Jean station. There are large mines in operation near by, and a settlement has grown up around them. The supply of water is large and its quality is indicated by the name.

323. *Piute Springs, Lincoln County* (I-11).—These springs are about 13 or 14 miles from Barnwell station (Manvel post-office), just east of the California-Nevada line, in the Piute Range. The main road from Barnwell to Searchlight runs about 3 miles north of them, but there is a dim trail between these places that passes the springs. Their exact location can best be ascertained by inquiries at the railroad station. The water issues from the granite that forms the axis of this range, and is pure and sweet. Other Piute Springs (No. 149) lie in Piute Pass, about 20 miles south.

INDEX.

A.

Page.

Agua Caliente Springs, Cal., description of. 85
Agua Dulce Springs, Cal., description of... 80
Alamo Bonita Springs, Cal., description of. 80
Alamo River, description of... 15
Alkali Spring, Nev., description of... 89
Alverson, C. S., work of... 8
Amargosa River, description of... 9–10, 14
water of... 9–10
Amboy-Dale route, description of... 28
Arab Spring, Cal., description of... 37
Argus Mountains, spring in... 39
Arrowweed, water near... 20
Arsenic springs, nonexistence of... 15, 48–49
Artesian water, development of... 29–30
Aztec Well, Cal., description of... 81

B.

Bailey, G. E., work of... 7
Banning-Dale route, description of... 29
Barnwell route, description of... 27
Barrel Springs, Inyo Co., Cal., description of... 31
Barrel Spring, San Bernardino Co., Cal., description of... 61–62
Barrel Springs, Nev., description of... 87
Bedding, nature of... 22
Bedrock Spring, Cal., description of... 52
Bennet's Wells, Cal., description of... 38
Bird Spring, Cal., description of... 33
Bitter Spring, Cal., description of... 61
Blackhawk Well, Cal., description of... 51
Black Mountains, Cal., wells on... 38
Black's Well, Cal., description of... 58
Blackwater Well, Cal., description of... 52–53
Bonanza Springs, Cal., description of... 69
Bonanza Well, Cal., description of... 66
Bonnie Clair, Nev., wells at... 88
Borax Well, Cal., description of... 62–63
Borego Spring, Cal., description of... 82
Bowlder Well, Cal., description of... 78
Box S ranch, Cal., wells at... 71–72
view at... 66
Brier Spring, Nev., description of... 88–89
Brook Spring, Cal., description of... 46
Brown's Well, Cal., description of... 79
Buckhorn Spring, Cal., description of... 64
Bullfrog routes, description of... 27–28
Bullion Mountains, Cal., spring on... 74
Burcham ranch, Cal., water at... 71
Burro Spring, Cal., description of... 32

C.

Cactus Flat Springs, Cal., description of... 72–73
California, springs in, descriptions of... 31–87
Camps, location of... 16–17
Cane Springs, Nev., description of... 90
Canteens, need for... 24
Canyon Springs, Riverside Co., Cal., description of... 81
Canyon Springs, San Bernardino Co., Cal., description of... 60
Carrijo, Cal., springs at... 86
Cave Rock Springs, Nev., description of... 89
Cave Springs, Cal., description of... 47
Chapman, R. H., work of... 8
China ranch, Cal., road to... 40–41
springs at... 41
China Well, Cal., description of... 42
Chinese pusley, water near... 20
Chuckwalla Spring, Cal., description of... 82
City Wells, Cal., description of... 51
Clark Well, Cal., description of... 82
Clay, water in... 19
Climate, description of... 11–13
Clothing, nature of... 22–23
Cloudbursts, violence of... 12
Coachella, Cal., wells at... 79
Cold Spring, Cal., description of... 31–32
Coleman-Mohave route, description of... 33
Coleman Springs, Cal., description of... 36
Colony well, Cal., description of... 68
Colorado desert, description of... 11
location of... 5
Confidence Springs, Cal., description of... 39
Conglomerate, water in... 19
Coolgardie, Cal., wells near... 58, 59
Copper Wells, Cal., description of... 73
Corn Creek Springs, Nev., description of... 91
Corn Springs, Cal., description of... 81
Coso, Cal., springs at... 37
Cottonwood Creek, description of... 34–35
Cottonwood Springs, Riverside Co., Cal., description of... 78
Cottonwood Springs, San Bernardino Co., Cal., description of... 56–57, 66
Cottonwood Springs, Nev., description of... 93
Cove Springs, Cal., description of... 66
Cow Creek, description of... 36
Cow Spring, Cal., description of... 38
Coyote Holes, Cal., springs at... 49–50, 75
Coyote Well, Imperial Co., Cal., description of... 86
Coyote Well, San Bernardino Co., Cal., description of... 60–61
view of... 60
Crater Spring, Cal., description of... 56
Creosote bush, water near... 21
Cronese Spring, Cal., description of... 61
Crystal Spring, Cal., description of... 37
Crystal Springs, Nev., description of... 93
Culture, extent of... 6–7
Cunningham Spring, Cal., description of... 50
Currie Wells, Nev., description of... 89
Cushenbury Springs, Cal., description of... 72

D. Page.

Daggett route, description of 27
Dale-Amboy route, description of 28
Dale-Banning route, description of 29
Dale-Mecca route, description of 28
Dale Pump, Cal., water at 76
Danby, Cal., wells near 70
Dante Spring, Cal., description of 62
Data, accuracy of 7–8
Daylight Spring, Cal., description of 34
Dead Man's Hole, Cal., description of 74
Dead Man's Lake, Cal., well at 71
Death Valley, view in 10
Death Valley region, description of 9–10
location of 5
routes in, description of 26–27
Deep Springs, Cal., description of 31
Desert region, area and location of 5
area and location of, map showing .. Pocket.
character of 8–9
industrial development in 6–7
mineral resources of 6
watering places in 5–6
Desert Wells, Kern Co., Cal., description of. 57
Desert well, San Bernardino Co., Cal., description of 76
Distances, pacing of 25
Dos Palmas, Cal., springs at 80–81
Drinking, restriction on 23–24
Dry lakes, occurrence and character of 17–18
wells at 18

E.

Emigrant Springs, Cal., description of 35
Epsom salts, occurrence of 15
Esmeralda Co., Nev., springs in 87–88

F.

Fairbanks ranch, Nev., description of 90
Farmer, Nev., water at 88
Faults, occurrence and character of 11
Feed, provision for 21–22
Fenner, Cal., wells at 66–67
Figtree John's Springs, Cal., description of. 83–84
Fish Springs, Cal., description of 83
Flowing Wells, Cal., description of 65
Food, nature of 23
Fountain Springs, Cal., description of 35
Fourth of July Springs, Cal., description of. 44
Francis Well, Cal., description of 57
Franklin Well, Cal., description of 36–37
Freeman, Cal., springs near 42
Frémont, J. C., on Salt Spring 49
Frémont's trail, description of 25
Frinks Springs, Cal., description of 84
Fuel, scarcity of 24

G.

Garlic Spring, Cal., description of 61
Garlock, spring near 50
Getting lost, precautions concerning 24–25
Glaubers salt, occurrence of 15
Goffs, Cal., well at 67
Goldbelt Spring, Cal., description of 33
Goldfield route, description of 28
Gold Mountain, Nev., well at 87
Goleta Spring, Cal., description of 57–58

Page.

Good Springs, Nev., description of 93
Government Holes, Cal., description of 63
Granite, water in 19
Granite Mountain, Cal., springs on 68
Granite Tanks, Cal., description of 81
Granite Wells, Cal., description of 53
Grant Springs, Cal., description of 58
Grapevine ranch, Cal., springs at 31
Grapevine Springs, Inyo Co., Cal., description of 31
Grapevine Springs, Kern Co., Cal., description of 42
Gravel, water in 19
Great Trough, location and character of ... 10–11
Greenwater, Cal., springs at 38

H.

Haggin Well, Cal., description of 50
Halloran Springs, Cal., description of 56
Hanna Well, Cal., description of 84
Harper Lake, Cal., well at 65
Harper's Camps, Cal., wells at 54–55
Harper Well, Cal., description of 85
Hector, Cal., spring near 69
Hidden Springs, Cal., description of 44
Hinkley Well, Cal., description of 65
Hole in the Rock Spring, Cal., description of 34
Hornet Springs, Nev., description of 91
Horsethief Spring, Cal., description of 50
Hot Springs, Cal., description of 39

I.

Ibis, Cal., wells at 67
Imperial Co., Cal., springs in 84–86
Indian Spring, Esmeralda Co., Nev., description of 87
Indian Springs, Inyo Co., Cal., description of 32
Indian Springs, Kern Co., Cal., description of 64
Indian Springs, Lincoln Co., Nev., description of 91
Indian Spring, San Bernardino Co., Cal., description of 59
Indian Well, Riverside Co., Cal., description of 79
Indio, Cal., wells at 79
Inyo Co., Cal., springs in 31–42
Iron Chief Well, Cal., description of 78
Irrigation, development of 29
Ivanpah route, description of 27–28
Ivanpah Well, Cal., description of 57

J.

Jacumba Springs, Cal., description of 87
Johannesburg route, description of 26–27
Johnnie, Nev., spring near 91

K.

Kane Spring, Imperial Co., Cal., description of 85
Kane Springs, Kern Co., Cal., description of. 50
Kane's Spring, San Bernardino Co., Cal., description of 69
Kane's Wells, Cal., description of 59
view of 60
Keane Spring, Cal., description of 34

Page.

Keeler-Mohave route, description of 26
Kern Co., Cal., springs in..... 42, 57
Kessler Springs, Cal., description of..... 56
Kevidrup Spring, Nev., description of..... 90
Kingston Springs, Cal., description of..... 49
Klinefelter, Cal., springs at..... 67
Klinker Mountain, wells on 51
Kramer, Cal., wells near..... 65

L.

Lander Well, Cal., description of..... 42
Langford Well, Cal., description of..... 61
Las Vegas route, description of..... 28
Leach's Spring, Cal., description of 44–45
Lead Spring, Cal., description of..... 54
Le Conte Springs, Cal., description of..... 68–69
Lightfoot Well, Cal., description of..... 78
Limestone, water in..... 19
Lincoln Co., Nev., springs in..... 92–93
Lone Willow Spring, Cal., description of... 44
Lost. *See* Getting lost.
Lost Horse Spring, Cal., description of..... 77
Lucerne Valley, well in..... 72

M.

McCain Springs, Cal., description of 84–85
McCoy Spring, Cal., description of..... 82
McDonald Spring, Nev., description of..... 89
Magnesia Spring, Cal., description of 77
Manse Springs, Nev., description of..... 91–92
Map of desert region ..... Pocket.
accuracy of..... 7
Marl Spring, Cal., description of 63
Mascot Spring, Cal., description of..... 69
Mason ranch, Cal., springs at 85
Mean's Well, Cal., description of..... 73
Mecca, Cal., springs at 80
Mecca-Dale route, description of..... 28
Mellen, wells at 70–71
Mesquite, water near..... 20
Mesquite Spring, Inyo Co., Cal., description of..... 32
Mesquite Spring, San Bernardino, Cal., description of 75
Mesquite Springs, Nev., description of 92
Mesquite Well, Cal., description of 85
Mesquite Wells, Nev., description of..... 93
Mexican Camp Spring, Nev., description of 89
Mill Camp, Cal., springs at..... 81
Miller's Well, Cal., description of 76
Miller Wells, Nev., description of..... 90–91
Mineral resources, development of..... 6
Mohave-Coleman route, description of..... 36
Mohave Desert, location of..... 5
Mohave-Keeler route, description of..... 26
Mohave River, description of 10, 14
Mono County, Cal., springs in..... 31
Mountain Palm Springs, Cal., description of..... 85
Mountains, springs and tanks in 17
Mountain Springs, Cal., description of..... 86–87
Mountain Spring, Nev., description of..... 92
Mud Springs, Nev., description of..... 89
Mule Springs, Cal., description of..... 84
Murphy's Well, Cal., description of..... 58

N.

Page.

Needles, Cal., wells at..... 67–68
Needles-Parker route, description of 28
Nevada, springs in..... 87–93
Newberry Springs, Cal., description of..... 65
New England Springs, Nev., description of. 93
New River, description of..... 15
Nye Co., Nev., springs in 88–92

O.

Oasis, Cal., springs at..... 31
Oasis Valley, Cal., springs in..... 89
Old Camp, Nev., spring at 87
Old Spanish trail, description of..... 26
Old Woman Mountain, Cal., spring on..... 74
Old Woman's Springs, Cal., description of.. 70, 73
Ord Spring, Cal., description of..... 68
Out West Well, Cal., description of..... 63–64
view of 10
Owens River, description of..... 14
Owl Springs, Cal., description of..... 45–46

P.

Pachanca Springs, Cal., description of..... 50
Packard Well, Cal., description of 79
Pahrump, Nev., springs near..... 91
Palmdale, Cal., springs at..... 77
Palmetto, Nev., water at 87
Palm Springs, Riverside Co., Cal., wells at. 77
Palm Springs, San Diego Co., Cal., description of..... 85
Palm Well, Cal., description of..... 78
Palo Verde Mountains, Cal., description of. 82, 84
Paradise Springs, Cal., description of..... 59–60
Parker-Needles route, description of..... 28
Peacock Springs, Cal., description of..... 69
Pilot Springs, Cal., description of 53–54
Pinkham, C. A., work of 8
Piñon Piné Well, Cal., description of..... 78
Piute Springs, Cal., description of..... 64
Piute Springs, Nev., description of..... 93
Poison Spring, Cal., description of..... 34
Poison springs, nonoccurrence of 15, 48–49
Precipitation, records of..... 12–13
Providence Wells, Cal., description of..... 66
view of 66
Provisions, nature of 23
Purslane, water near..... 20

Q.

Quail Springs, Cal., description of..... 43, 45, 75

R.

Rabbit Springs, Cal., description of 71
Railroad Tank, Nev., description of..... 90
Railroads, construction of..... 6–7
Rainfall, records of..... 12–13
Rest Spring, Cal., description of..... 32
Resting Springs, Cal., description of 39–40, 41
Ricardo, springs near..... 50
Riggs Well, Cal., description of..... 55–56
Ring Well, Cal., description of 33
Rivers, description of 13–15
Riverside Co., Cal., springs in..... 77–84
Rock Corral, Cal., spring at 73
Rocks, water in 18–20

Page.

Rock Springs, Cal., description of..... 64
Rodriguez, Cal., wells at 64
Rodriguez Lake, Cal., spring at 64–65
Rose Springs, Cal., description of 37
Rose's Well, Nev., description of..... 90
Ruiz Well, Cal., description of 33

S.

Saccatone Springs, Cal., description of..... 57
Saline Valley Well, Cal., description of 33
Salt Creek Wells, Cal., description of..... 34
Salt grass, water near 21
Salton Sink, location and character of..... 10
Salt Spring, Cal., description of..... 48–49
water from, poison in 48–49
Salt Well, Inyo Co., Cal., description of.... 35
Salt Well, San Bernardino Co., Cal., description of..... 43
San Bernardino Co., Cal., springs in 43–77
San Bernardino Mountains, spring on..... 72
Sand, water in..... 18–19
San Diego Co., springs in..... 84, 85–87
Sand Springs, Cal., description of 31
Sandstone, water in..... 19
Sandy, Nev., springs near..... 93
Saratoga Springs, Cal., description of..... 47
roads to..... 48
Schist, water in..... 19–20
Searchlight route, description of..... 28
Searles, Cal., springs near 42–43
Searles Lake, Cal., springs near 43
Searles Springs, Cal., description of 42
Seattle Well, Nev., description of 88
Seventeen Palms Springs, Cal., description of..... 82–83
Shale, water in 19
Shaves Well, Cal., description of 80
Siam, Cal., wells near..... 69–70
Silver Lake, Cal., wells at 55
Sinks, occurrence and character of 17–18
wells at..... 18
Skilling Wells, Cal., description of 51
Slate Range, Cal., springs in..... 43
Soda Lake, location and character of 10, 15
spring and wells at and near..... 62, 63
Soda Springs, Cal., description of 83
Spanish trail, old; description of..... 26
Springs, descriptions of 31–93
descriptions of, symbols used in..... 30–31
location of, map showing..... Pocket.
occurrence and character of 15–16, 17
Squaw Spring, Cal., description of 51
Staininger's ranch, springs at 31
Star Springs, Cal., description of..... 58
Stirrup Tanks, Cal., description of 78
Stovepipe Wells, Cal., description of..... 34
Stubby Springs, Cal., description of 77
Stump Spring, Nev., description of..... 92
Sulphur Springs, Cal., description of..... 75–76
Summit Diggings, Cal., springs at..... 51
Sunflower Spring, Cal., description of..... 70
Sunset Springs, Cal., description of..... 86
Surprise Spring, Cal., description of..... 73–74
Surveyor's Well, Cal., description of..... 33
Sweetwater Springs, Cal., description of... 49
Symbols, use of, for springs shown on map. 30–31

T.

Page.

Tanks, location of..... 17
Teams, choice and care of..... 21
Tecopa Well, Cal., description of..... 41–42
Temperature, records of..... 12
Thorp Mill, Nev., description of..... 88
Tiefort Mountain, Cal., well at..... 54
Toltec, Cal., wells at..... 56
Tomaso Springs, Cal., description of 55
Tonopah Well, Nev., description of 88
Tools, need for..... 22
Topopah Spring, Nev., description of 90
Toro Springs, Cal., description of..... 79–80
Traveling, hints on..... 21–25
routes for..... 25–29
Triangle Spring, Cal., description of..... 33
Tule Springs, Cal., description of..... 32, 38, 41
Tule Springs, Nev., description of..... 92
Tules, water near..... 20
Tunnels, drainage, uselessness of 18
Turtle Mountains, Cal., description of..... 77
Twenty-nine Palms Spring, Cal., description of 76

V.

Vallecito Springs, Cal., description of..... 84
Valley Spring, Cal., description of..... 46
water from, analysis of..... 46
Valley Wells, Cal., description of..... 56
Vegas Springs, Nev., description of 92
Vegetation, character of 20, 21
water near..... 20–21
Victorville, Cal., well at..... 68
Victorville routes, description of..... 28–29
Vontreger Springs, Cal., description of..... 64

W.

Warren's ranch, Cal., springs at..... 75
Warren's Well, Cal., description of..... 75
Washington Tank, Cal., description of..... 78
Water, boiling of 23
discovery of 16–21
source of..... 13
See also Rivers; Springs; Wells.
Water Station, Cal., wells at..... 57
Wells, concealment of..... 16
West Wells, Cal., description of..... 74–75
Wheeler Spring, Cal., description of..... 54
Whitney Spring, Cal., description of..... 54
Wilbur Well, Cal., description of..... 73
Wild Rose Spring, Cal., description of..... 37–38
Willard Lake, Cal., well at..... 52
Williams Well, Cal., description of..... 55
Willow Spring, Esmeralda Co., Nev., description of..... 88
Willow Springs, Inyo Co., Cal., description of..... 32, 37
Willow Springs, Kern Co., Cal., description of..... 51
Willow Spring, Nye Co., Nev., description of..... 88
Willow Springs, San Bernardino Co., Cal., description of 60, 65–66, 69
Wilson's Spring, Nev., description of..... 93

Y.

Yuba Springs, Cal., description of..... 86

GENERAL MAP

SHOWING APPROXIMATE LOCATION OF

BETTER KNOWN SPRINGS AND WELLS

IN THE

MOHAVE AND ADJACENT DESERTS

SOUTHEASTERN CALIFORNIA AND

SOUTHWESTERN NEVADA

0 10 30 50 5 miles

1908

LEGEND

- Spring
- Well
- Pumping plant
- Flowing well

This graph is compiled from ... sheets ... for ... and the ...

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

WATER-SUPPLY PAPER 225

GROUND WATERS

OF THE

INDIO REGION, CALIFORNIA

WITH A SKETCH OF THE

COLORADO DESERT

BY

WALTER C. MENDENHALL

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CONTENTS.

	Page.
Introduction	5
Exploration and development of Colorado Desert	6
Geography	7
Geologic sketch	10
Structural features	10
Origin of the desert lowland	14
Late development of the Colorado Desert	17
The desert floor	20
Slope of floor	20
Development of the Imperial canal system	21
Inflow of the Colorado	22
The valley deposits	24
Classification of materials	24
Delta silts	25
Consolidated Tertiary beds	25
Sand dunes	26
Saline deposits	27
Water resources	28
Rainfall and drainage	28
Underground waters	31
Limits of origin	31
Source and character of the underground supply	34
Present development and controlling conditions	35
Need of conservation	36
Future of the water supply	37
Effect of the filling of the Salton Basin	38
History of development of the Indio region	40
Cost of reclamation and development	41
Soils and crops	42
Maps and tables	44

ILLUSTRATIONS.

Page.

PLATE I. Map of Salton Sink, California ..... In pocket.
II. Red Canyon northeast of Mecca 10
III. *A*, Calcareous incrustation on granite along old water line; *B*, Canyon cut in Tertiary alluvial sandstones northeast of Mecca 14
IV. The "water line" about the base of a granite outlier southwest of Coachella 18
V. The old water line and the new lake above Fish Springs 20
VI. *A*, New River in flood near the Five Headings; *B*, A characteristic recent dry arroyo in the desert; *C*, New River in flood, northwest of Imperial; summer of 1905 22
VII. *A*, Telegraph pole near Palm Springs station, deeply cut by wind-blown sand; *B*, Bowlder of gneiss near Palm Springs station, etched by wind-blown sand 26
VIII. Eastern border of sand-dune area west of Mammoth station 28
IX. *A*, Group of active mud volcanoes west of Imperial Junction; *B*, General view of quiescent mud volcanoes near Imperial Junction 32
X. *A*, A desert homestead south of Indio; *B*, Earthen reservoir near Indio; *C*, Cottonwoods, 2 to 4 years old, near Coachella, Cal 36
XI. View of the Salton Basin from the west side, after the inflow of the Colorado 40
XII. Map showing wells, artesian areas, and irrigated lands in the Indio region ..... In pocket.
FIG. 1. Diagrammatic section across Coachella Valley through Mecca 12
2. Section of Southern Pacific well at Indio, Cal 33
3. Section of Southern Pacific well at Mecca, Cal 33
4. Section of Southern Pacific well at Mortmere, Cal 33
5. Diagrammatic section illustrating course of ground waters through Coachella Valley 39

GROUND WATERS OF THE INDIO REGION, CALIFORNIA, WITH A SKETCH OF THE COLORADO DESERT.

By Walter C. Mendenhall.

INTRODUCTION.

Water is the first requisite to the existence of all life; hence everywhere in the arid West the question of water supply is of paramount importance. Agricultural and industrial activity can not continue without water; mining is seriously handicapped by small supply; and in the more arid districts generally all hope of permanent human occupation depends upon the possibility of developing or introducing water in relatively large quantities.

Those deserts whose watering places are widely separated are dreaded by travelers and, if possible, avoided. The number of desert tragedies has not been reduced by the building of railroads within the last quarter century, because the lessened danger has been balanced by a greater influx of inexperienced travelers.

The Colorado Desert in southern California is one of the most sensationally interesting as it has been one of the most truly arid parts of western North America. Since the first journeys were made across it by the mission fathers to extend the influence of their church from the older settlements in Mexico and New Mexico westward and northward into California, it has been in ill repute among travelers.

For more than a hundred years travel between the settlements east of Yuma and those on the California coast north of San Diego has followed a highway that crosses this desert. By this route the missions of Mexico, New Mexico, and Arizona were connected with those of San Diego, San Luis Rey, Capistrano, San Bernardino, San Gabriel, and San Fernando. After the Mexican cession and before the building of the great railways a transcontinental stage route crossed it, and American traders occasionally drove freight teams from Yuma to San Bernardino along a course which was later followed closely by the Southern Pacific Railroad. This longer road, which traversed the desert from end to end, was less generally used than one which crossed it from east to west and entered the mountains by way of San Felipe Creek and Warners Valley, so reaching

San Jacinto and later Los Angeles with less of desert and more of mountain travel.

EXPLORATION AND DEVELOPMENT OF COLORADO DESERT.

One of the most satisfactory published accounts of the Colorado Desert is that prepared by the first of the American scientific explorers who have visited it. In 1853 a military expedition, led by Lieut. R. S. Williamson, explored the southern part of the San Joaquin Valley, the passes leading from it to the Mohave Desert, those connecting this desert with the valley of southern California, and, finally, those which connected that valley with the Colorado Desert. The primary object of the expedition was to determine feasible routes for railroad construction, but, as was usual at that time, a naturalist was attached to the expedition to report on matters of scientific interest that might be observed along the route of travel. This assignment was held by Prof. William P. Blake, and the report [a] which he published after the expedition had been disbanded presents the most complete and graphic scientific account of the physical features of this section of arid America that is yet available.

The party to which Professor Blake was attached entered the desert from San Bernardino through San Gorgonio Pass. The first stop was made at Palm Springs and the second at Indian Well, in the northwestern end of the desert, now usually called the Coachella Valley. The explorers visited the springs at Toro and Agua Dulce, which have since been included in the Indian reservations and were then centers about which Indian habitations were clustered. Below Figtree John's the expedition encountered difficulties in its attempt to reach the old stage road which followed Carrizo Valley from the desert floor to the base of the Peninsula Range. Along the west side of Salton Sea there is a wide area in which potable water was at that time very scarce, and it was only after several of the animals of their pack train were nearly exhausted that the members of the expedition finally found water in the vicinity of Salt Creek, near what are now known as "McCain Springs."

Professor Blake describes the physical aspect of the desert, the effects of wind erosion upon it near Palm Springs, the old water line along the western border, and such other geological phenomena as were observed; and he mentions the springs which he visited during his journey or about which he could obtain reliable information. It is interesting to note that in the course of his discussion he predicted

[a] Reports of explorations and surveys to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, made under the direction of the Secretary of War in 1853–54, according to acts of Congress of March 3, 1853, May 31, 1854, and August 5, 1854: Sen. Ex. Doc. No. 78, 33d Cong., 2d sess., vol. 5, pt. 2; Geological report by Wm. P. Blake, geologist and mineralogist of the expedition.

that artesian water would be found beneath the surface of the desert. Thirty-five years afterwards this prediction was fulfilled, although the waters are found in the Pleistocene alluvium instead of in the consolidated Tertiary rocks, where Professor Blake expected that it would be found.

The desert was made much more accessible in 1879 by the construction through it of the main line of the Southern Pacific Railroad from New Orleans to San Francisco. Extensive travel across it by wagon ceased with the construction of the railway, and at the various stations along the line water may always be procured, so that the danger of death from thirst has been greatly reduced.

In 1888 the Southern Pacific engineers, in searching for water for their locomotives and station houses, obtained small artesian flows at Thermal and Coachella. Six years later a successful well was put down at Walters, now called Mecca, thus proving definitely the existence of water under this portion of the desert basin with sufficient pressure to rise to the surface. Attempts to sink wells with the ordinary well rigs in use in adjacent parts of southern California are not, however, attended with success here, because of thick strata of fine sand, through which it has been found extremely difficult to sink the casing and keep the tube in alignment by the standard methods. Experiment has proved, however, that the hydraulic method, in use for shallow wells in the coastal plain of southern California, is well adapted to this desert region. As a result of this discovery numbers of successful wells have been sunk, and the reclamation of the northwestern arm of the Colorado Desert is under way (Pl. X, *A*, *B*, and *C*) through the utilization of the waters thus developed.

At about the same time that the underground waters began to be used extensively about Indio, the California Development Company, by utilizing an old distributary of Colorado River, carried waters from that stream to a part of the desert that lies in Imperial County, near the Mexican line, and that is now called the Imperial Valley. When this water had been successfully conducted out upon the old desert floor it was found that the soils over much of the area were very fertile. Settlers hastened to the region, successful ranches were established, and now several thousand people are living in the heart of what was once a most dreaded waste. Thus the transformation of the southern, broader end of the Colorado Desert was begun.

GEOGRAPHY.

The Colorado Desert lies in a wide valley, the northwest extension of the great depression whose southern end is occupied by the Gulf of California. (See Pl. I.) This valley extends northward to San Gorgonio Pass, in Riverside County, 200 miles above the present

head of the gulf. It is bounded on the west by the Peninsula Range and on the east by a network of desert ranges, known in their various parts as the Cottonwood, the Ironwood, and the Chuckawalla Mountains. The Peninsula Mountains do not present a regular front toward the desert. This eastern face of the range exhibits a series of salients and reentrants, which result in great steplike irregularities in the western wall of the valley. The first and least prominent of the salients seen in passing from San Gorgonio Pass southward is formed by the eastern base of San Jacinto Mountain. Back of it lies the lower valley of Palm Canyon, whose width increases that of the desert to 9 or 10 miles.

The next of the great Peninsula salients is formed by the Santa Rosa ridge, whose southern end lies just west of the Salton Sea. Back of this lies Borego Valley and the canyon of Coyote Creek. At this point the width of the desert increases to 35 miles. Still farther south Carrizo and Black mountains form another salient, and below them the desert attains its maximum width of nearly 50 miles. At the international boundary is Signal Mountain, a northern outlier of the Cocopa Range, which divides the lower portion of the desert into an eastern part, occupied by the Colorado delta, and a western part, lying below sea level at its lowest point and containing the Laguna Salada, a fluctuating body of bitter water.

The barren ranges that form the eastern wall of the desert are the southeastern continuation of the San Bernardino Mountain mass. They are irregular in arrangement and altitude, but there is not the system in their irregularity which is displayed by the Peninsula Range. They are interrupted by high passes, by which they may be traversed to the valley of the Colorado River of the West, which lies east of them; and in a general way they diminish in altitude toward the south until, in the vicinity of Yuma, they disappear, and the desert unites around their southern end with the valley of the Colorado River. These mountains are typical arid ranges, barren of all normal types of vegetation. Here and there characteristic distorted desert growths, like the barrel cactus, the ocatilla, the cholla, the greasewood, the ironwood, and the palo verde are found sparingly distributed over the rocky mountain sides.

The lower slopes of the Peninsula Range west of the desert are as barren as the mountains east of it, but as the crest is approached the more humid conditions which prevail on the Pacific slope and extend for short distances over the crest toward the desert produce more abundant vegetation. Conifers of a few types, palms in some of the lower, better-watered canyons, grasses, the hardier varieties of chaparral, and other common southern California plant forms are found. Needless to say, practically all the perennial streams that flow to the desert rise on the upper slopes of the ranges to the west and north of it.

The floor of the desert itself exhibits various physical aspects. The portion first reached in passing into it from Redlands or San Bernardino is a region of sand dunes. Practically the entire valley bottom here is a waste of shifting sand, in almost constant motion through the action of the strong winds that blow at frequent intervals from San Gorgonio Pass and the high mountains which flank it on the north and south.

Just south of the sand-dune area and below the sea-level contour the valley floor is silt covered, relatively smooth, and sustains a luxuriant growth of desert vegetation. The mesquite bush here attains the dignity of a tree, and forms which are dwarfed in less fertile and drier sections of the desert here grow luxuriantly, because the artesian waters, imperfectly confined beneath the partially pervious clays that underlie the surface, seep toward it and furnish a supply of moisture which for these desert plants is unusually abundant.

Farther southeast, about the borders of the Salton Sea, strongly alkaline areas are found, and here the desert floor, smooth or sharply gullied and gently sloping, is generally devoid of vegetation. At the lowest point in the valley, now occupied by the Salton Sea, the alkalies had accumulated to such an extent as to form a true "salina," and salt was mined there in a commercial way for many years before the inflow of the Colorado.

Still farther south, beyond the Salton Sea, in the region now known as the Imperial Valley, the desert is floored with a fine laminated silt, deposited in past centuries by the Colorado River. This region appears level to the eye, but in reality slopes toward the Salton depression. Before irrigation and settlement only indefinite channels, seldom filled with water, extended from the area of annual summer overflow in the vicinity of the lower Colorado toward the sink; but in the last few years two of these channels—New and Alamo rivers—have been deepened and enlarged, until they are now continuous deep cuts with wall-like banks from a point south of the Mexican line to the shores of the new lake.

As a physical feature the Colorado Desert is continuous from San Jacinto Peak southeastward to the head of the Gulf of California. As a result of settlement and the attendant development, however, different portions of the lowland have been given different names, which have no physiographic significance but are based entirely upon human occupancy. The Imperial Valley, the most important of these subdivisions, has been outlined. It occupies the southernmost part of that portion of the Colorado Desert lying within the United States. The northern, narrow end, lying between the base of San Jacinto Peak and the margin of the Salton Sea, is known as the "Indio region," or the Coachella Valley. The fertile and cultivated portions of this section lie, for the most part, south of Indio and

below the sea-level contour, settlement and development being controlled entirely by the occurrence of underground waters, which are most abundant and accessible within the limits outlined above.

East of Imperial Valley and extending from Mammoth station southward to the international boundary is a belt of sand dunes, 6 or 7 miles wide and 40 or 50 miles long, lying east of the well-marked old beach line, while west of the valley is the sandy beach marking the western shore of the old lake, between which and the base of the mountains is a belt of alluvium, such as usually borders desert mountains.

GEOLOGIC SKETCH.

STRUCTURAL FEATURES.

The west wall of the Colorado Desert from the vicinity of Banning to the southeastern point of the Santa Rosa Mountains is made up exclusively of massive plutonic rocks of granitic or acid dioritic type, and of metamorphic rocks which are intruded by the igneous masses. The axis of the San Jacinto Mountains appears to consist of an unaltered dioritic mass, about whose periphery there is a zone of schist and gneisses with occasional bodies of highly altered limestone. These metamorphic rocks are found along the southern border of the desert in the vicinity of White Water and Palm Springs, and are believed to exist some miles east of the latter point, along the southern border of the Conchilla Desert. The projecting points in the neighborhood of Indian Well and at places farther south, toward Toro, are formed of massive granitic rocks, but still farther south, back of Figtree John's, the wall of the Santa Rosa ridge again proves to be geologically more complex. Diorites occur in this vicinity in small masses, but basic schistose rocks and marmorized limestones are found in large bodies.

None of the rocks of this type have any value as water bearers. So far as water in commercial quantities is concerned they are practically impervious. East and west of these metamorphic and intrusive masses much younger rocks of totally different character cover extensive areas. West of the San Jacinto mass blue and buff shales, with occasional traces of vegetal remains and of fresh-water shells, extend along the ridge between San Timoteo Canyon and the San Jacinto Valley nearly to Colton. These impervious shales are overlain unconformably by heavy bodies of alluvium made up of well rounded river cobbles, sands, and clays intermingled or in alternating beds. In this region the attitude of these rocks and their porosity make them valuable water bearers, and in the Yucaipe Valley and San Timoteo Canyon near Redlands deep wells have been drilled in them which yield water in sufficient quantities

RED CANYON, NORTHEAST OF MECCA.

to irrigate near-by lands. The age of these consolidated sediments is not known with certainty, but it is probably Pliocene.

East of the point of the Santa Rosa Mountains rocks that are similar in general character though probably older, but about the details of whose distribution and structure very little is known, extend southward to the Mexican boundary. These areas were traversed by Professor Blake from the Santa Rosa Mountains to Carrizo Creek, and in his report upon that region he describes them as highly folded and exhibiting the usual Tertiary sedimentary succession of sandstone and shale.

More detailed work has been done in the vicinity of Carrizo and Black mountains by the writer, and something has been learned of the stratigraphic sequence and of the structures there. The basal members of the sedimentary series in Carrizo Mountain are usually conglomerates of limited thickness, 100 to 200 feet being about the usual measure. Overlying these are buff and greenish shales which are at least 1,000 feet thick, and may be much more. They are succeeded in turn by a body of soft shales, which in places show a pink tint and are interbedded with thin brown concretionary sandstones. These have a wide distribution over the western margin of the desert between Carrizo Mountain and the Cocopas. A few springs occur along the outcrop of the sandstone members of this series, but water in sufficient quantity and purity to be valuable for irrigation has not been developed in them, although a number of wells drilled in prospecting for oil have penetrated the rocks to depths of a thousand feet or more.

The age of the basal members of this sedimentary series in the Carrizo Valley is Miocene. The higher beds may be somewhat younger. The core of Black and Carrizo mountains which has served as a basement on which the sediments have been deposited, like the main range farther north and west, is a complex of metamorphic rocks and massive intrusives. Small patches of effusive lavas and associated tuffs also occur in this section, overlying the basement complex and interbedded in places with the lower members of the sedimentary series.

North and east of the Colorado Desert the relations are in a general way similar to those on the south and west sides. At the base of the north wall of San Gorgonio Pass is a belt of folded and faulted alluvial sediments, not more than 2 or 3 miles wide, which locally has been cut down by erosion and buried under modern wash. Wherever it remains, however, and is exposed for examination the rocks are seen to be coarse sandstones, gritty clays, and heavy conglomerates which have been thrown into complex attitudes and broken along many lines.

North of the sediments are the schists and massive rocks that make up the main body of the San Gorgonio Mountain mass. The

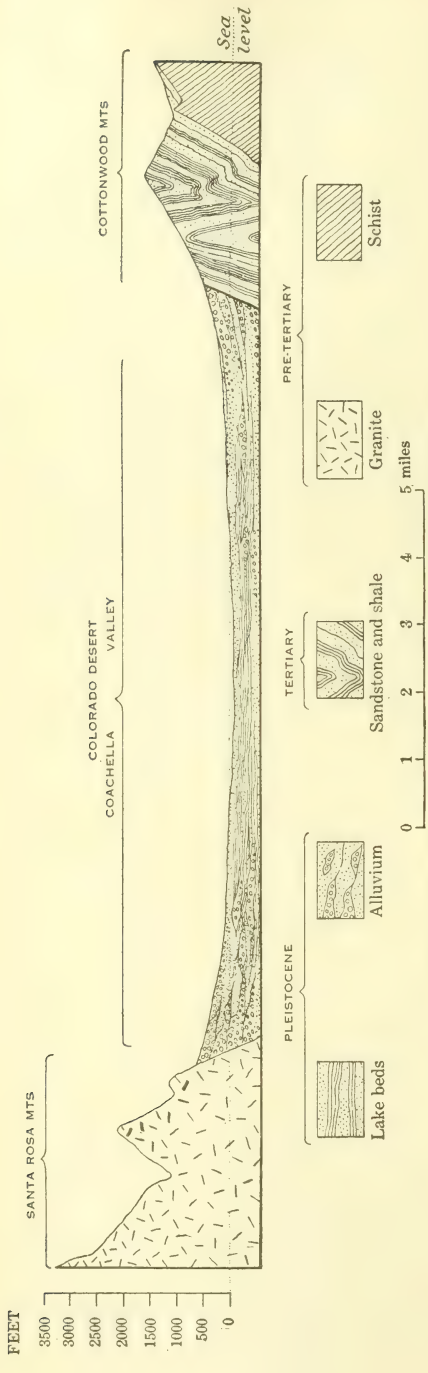


FIG. 1.—Diagrammatic section across Coachella Valley through Mecca.

contact between the metamorphics and the sediments here is a fault contact. North of Indio the normal valley filling of unconsolidated lake sediments and alluvium extends for a distance of approximately 2½ miles; beyond this lies a range of low foothills formed of folded Tertiary sediments, somewhat similar in general aspect to those in San Gorgonio Pass but not so coarse, probably because they lie at a greater distance from the source of the material of which they are composed. They are closely folded here, as elsewhere, and the exposures are so perfect that the succession of synclines and anticlines can be traced with the greatest exactness (fig. 1).

The northern wall of the valley back of Mecca has also been examined. Here a space of perhaps 2½ miles intervenes between the railroad and the first bed-rock exposures. The section of folded Tertiary beds and their relations to the older rocks are plainly shown in the box canyon that opens on the desert almost due north of Mecca (Pl. II). The basement rocks exposed near the head of this canyon are highly altered schists containing acidic dikes and quartz stringers. Directly upon these, with a normal depositional contact, rest from 1,000 to 1,200 feet of dark brownish-red sandstones and conglomerates (Pls. II and III,

B, and fig. 1). Overlying these, apparently conformably, are from 3,000 to 4,000 feet of yellowish sandstones and sandy shales containing masses of coarse conglomerate and alluvial material (fig. 1).

These sediments are all closely folded. They dip from the base of the beds toward the valley for 1½ miles, but this dip is interrupted just at the valley border by a sharp anticline, which brings to the surface again many of the beds that had passed below it at points farther north. No fossils have been observed in any of these sediments north of the desert, and as they are alluvial in character and probably in large part fresh-water deposits, they are unpromising fields in which to search for organic remains. For the same reason they are not regarded as particularly promising as sources of oil or gas. It is probable, however, that the porous rocks in the synclines contain small quantities of ground water, and that this water would flow to the surface if tapped at favorable points, but its quality is problematic. The waters of the Tertiary rocks generally in this part of the State contain much alkali in solution, and at many places are unfit for drinking or even for irrigating purposes.

This belt of folded sediments extends along the east side of the valley at least as far as Imperial Junction, but is less conspicuous than farther northwest because it has been worn down more completely by erosive action. Usually, however, it forms a zone between the higher desert mountains of metamorphic rock, from which it may be separated by a belt of overlying alluvial fans, and the relatively level lands of the central desert.

Between Imperial Junction and the Salton Sea are isolated outcrops of sandstone, and another outcrop within the valley is but a few miles northwest of the town of Imperial, near the bank of New River. This outcrop is nearly in line with Superstition Mountain, west of the river. This mountain is reputed to have a granitic axis and to be flanked by sediments, and the outcrop near Imperial is considered as the southeastward extension of the same ridge.

Besides these sedimentary rocks it is to be noted that a row of knobs of obsidian, pumice, scoriaceous lava, and tuff extends southwestward for several miles from a point about 6 miles west of Imperial Junction. Originally these masses stood out merely as rock knolls in the desert; now they are islands in the Salton Sea. These rock outcrops near the south end of the Salton Sea suggest that the valley filling may be relatively shallow here—that is, that bed rock may be nearer the surface than either north or south of this locality.

The relations between the sediments and the metamorphic complex that forms the desert ranges east of the valley were observed only in San Gorgonio Pass and at a point a few miles east of Mecca.

In the pass extensive faulting has taken place, and one of the fractures is between the sediments and the older rocks. Back of Mecca, however, a normal depositional contact is found, a true basal conglomerate forming the lowest member of the sedimentary series (Pl. II). The same conditions have been observed about Carrizo and Black Mountains, and are inferred at the southern end of the Santa Rosa group from general relations. Hence if the great Cajon-San Gorgonio fault extends into the desert it probably follows its axis closely, since it is not to be found along its borders. Here it is buried completely beneath the modern lake sediments, and its presence can be inferred only from isolated phenomena like the obsidian cones near Imperial Junction, with their accompanying solfataras, or from general physiographic evidence.

A sketch of the geologic phenomena of the desert would not be complete without further mention of these solfataras (Pl. IX). About 7 miles a little south of west of Imperial Junction, near the row of obsidian knobs already described, an interesting group of mud volcanoes existed before the area was flooded by the rising of the lake. Some of these were quite perfect cones with craterlets at top, others were in various stages of formation or destruction. The usual accompaniments of hot pools, gaseous emanations, sulphur and salt deposits, acidulated waters, and boiling mud pools were to be found here. Near the principal group were smaller groups of extinct or at least quiescent mounds. These mud volcanoes are regarded as representative of the last phase of the volcanic activity that produced the lava knobs in this part of the desert.

A more extensive field of mud craterlets is found about 40 miles south of the international boundary line, along the western shore of Volcano Lake. The forms that result from the activity and the phenomena generally are similar to those near Imperial Junction, but on a larger scale.

ORIGIN OF THE DESERT LOWLAND.

Of the details of the origin of the valley occupied in its southern part by the Gulf of California and at its northern end by the Colorado Desert, but little is known. It may be said, however, as a generalization, that it belongs to a type which physiographers describe as constructional—that is, it represents an area which has been depressed as a result of crustal movement, as contrasted with valleys due to erosion. There are many proofs of this. The fact that its rock floor is below tide, even in those parts north of the gulf where the actual surface is well above sea level, proves that a part at least of its position is due to actual subsidence of a block of the earth's crust, because erosive action can not extend below the ultimate base level, which is usually sea level. Wells drilled near Imperial indicate that

A. CALCAREOUS INCRUSTATION ON GRANITE ALONG OLD WATER LINE.

B. CANYON CUT IN TERTIARY ALLUVIAL SANDSTONES NORTHEAST OF MECCA.

there is no bed rock within a depth of 600 or 700 feet below tide, and others in the Coachella Valley and at Salton prove that at these places bed rock is at least 1,000 feet below sea.

The topographic character of the western margin of the desert within the United States and near the international boundary also indicates very distinctly the presence of fault lines along this margin. The eastern edge of the Peninsula Mountains is a marked fault scarp, throughout at least a portion of its length. The valley occupied by the Laguna Salada, west of Calexico, appears to be a dropped block. Salients like the Santa Rosa Mountains and the group south of San Felipe Creek, projecting toward the desert from the northwest, appear to be limited on one or the other side by faults. The Santa Rosa ridge itself is a particularly suggestive mountain mass. It has a steep, abrupt southwest face, with short drainage lines, and a relatively smooth and sloping northeast face, with long drainage lines. On its northeast face there are many large surfaces, comparatively unscarred by modern arroyos, which at once suggest remnants of an old eroded surface. In short it has the topographic characteristics of a faulted block tilted toward the northeast and plunging into the desert toward the southeast.

Little is known of the eastern desert border, but where it has been visited in the vicinity of Mecca there is no evidence of faulting, the rocks of which it is made up dipping toward the desert away from the old crystalline surface upon which they were deposited.

One of the most extensive faults in California runs southeastward through the coast ranges, north of the San Gabriel Mountains, through Cajon Pass, south of the San Bernardino Range, and through San Gorgonio Pass into the Colorado Desert. Here it is no longer traceable; but since, if projected, it would follow closely the axis of the desert valley, through the Salton Sink and southeastward toward the Gulf, it may well be even here one of the lines of weakness that has helped determine the position of the depression. As the entire basin is occupied by lake silts and alluvium of most recent origin, it is evident that unless movement had taken place along this fault at a very late date there would be no surface indication of it. Phenomena like the obsidian buttes 6 or 8 miles southwest of Imperial Junction and the group of solfataras seen there until submerged by the waters of Salton Sea may well be associated with a profound fracture of this nature. The other group of solfataras, 35 or 40 miles southeast of Calexico, near the base of the Cerro Prieto in Mexico, is distributed for 2 or 3 miles along a northeast-southwest line, parallel to the structures in the mountain ranges to the west.

All of this evidence, taken together, indicates strongly that the desert valley is associated with structures in which faults are prominent, and leads logically to the conclusion that the desert is a con-

structional depression due to the marked and probably irregular subsidence of a number of faulted strips.

The Tertiary (Miocene?) rocks which border the desert on either side seem, so far as their relations are known, to have been affected by much of the movement in which the desert originated. Carrizo Mountain, on the western margin of the desert, about 12 miles north of the Mexican line, is a knob of crystalline rocks surrounded by Miocene sediments that dip away in all directions at angles greater than the original angle of deposition. About 7 miles south of Carrizo Mountain the crystalline rocks of the main range are not flanked by Tertiaries, but pass directly beneath the alluvial cones of the desert border, as though the sediments had been faulted out there. Signal Mountain is flanked by late sediments on the north and south at least, and they have been folded in varying degrees of intensity. This same observation applies to the sandstones and shales that flank the Santa Rosa Mountains on the southeast, south, and west; and along the eastern border of the desert, wherever the sediments are exposed, from Whitewater River well down toward Yuma, they have been closely folded. One section studied (fig. 1) from Mecca northeastward to the crystallines, shows that the sediments rest directly upon the schists as they were originally deposited and dip from them toward the valley, the regular dip in this direction being interrupted by a single well-marked anticline. As a rule, then, the Tertiary sediments dip from the valley borders toward its axis, and, as a rule, also, along its axis they are well below sea level and are deeply buried under recent alluvium.

Distinctly within the valley, yet not far from its borders, are a few isolated exposures of the Tertiary bed rock that presumably forms its floor almost everywhere. Around some of the obsidian cones southwest of Imperial Junction lie beds of upturned and somewhat altered material that may represent a part of the valley basement, although it is more likely that they are a part of the Pleistocene filling indurated by volcanic action. Between these cones and the railroad are occasional exposures of sandstones that belong clearly to the Tertiary series. Beyond Imperial Junction to the east, north, and northwest are the folded clays and sandstones that make up the valley margins generally. Here, however, they are planed off to an even surface that slopes toward the lake.

A few miles west of Imperial, near the east bank of New River, is a single exposure of sandstone of the type familiar about Superstition Mountain. Indeed, it probably represents merely an extension to the southeast of the Superstition ridge. Elsewhere, so far as known, there are no rock exposures near the axis of the valley.

The conclusions as to the origin of the great depression occupied by the Colorado Desert and the Gulf of California, in so far as they

can be drawn from evidence at hand, are, then, that it is due to crustal movement—subsidence along a number of fault lines, or, perhaps, slight subsidence in this area combined with elevation in the areas east and west, leaving the desert not far below its original position; that at least a part of this movement has taken place since the Tertiary rocks were deposited—fossils prove the presence of Miocene beds, and clearly later rocks are probably Pliocene—and as associated solfataric phenomena and the derived land forms are so well preserved, it is likely that much of the movement is late Pliocene or Pleistocene.

LATE DEVELOPMENT OF THE COLORADO DESERT.

At a period that is geologically very recent indeed the long, narrow depression whose origin has been thus briefly indicated was occupied by the Gulf of California to a point far north of the present head of the gulf. It is probable that the gulf waters then swept inland to the base or nearly to the base of San Jacinto Peak, although all evidence which would enable us to fix its exact limits has been obliterated by still more recent geologic events. At that time the mouth of Colorado River was in the vicinity of Yuma, 60 miles in an air line north of where it now is. Presumably then, as now, it was discharging annually enough silt to cover 1 square mile to a depth of 53 feet with dry earth, equivalent to 1 cubic mile each century, cut from the great canyons in the upper Colorado and the Gila Valley and carried to the gulf. Running water will carry in suspension matter that quickly settles in still water, the settling process in this case being aided by the clarifying effect of the salt water.

As a result of these processes the Colorado delta was gradually extended southwestward toward the Cocopa Mountains, and when it reached them it had separated the old gulf into the present gulf and an inland sea. Delta growth, however, did not cease with the separation of the water body into two parts. Silt continued to be brought down the stream and to be deposited in its bed, along its banks, and in the still waters at its mouth. A stream by this process of deposition along its channel eventually builds the channel up until it is higher than the lands adjacent on either side. It is then in a condition of unstable equilibrium, and at some favorable time, as during an exceptional flood, it will break out of its immediate banks, and establish itself in some more favorable course. By this process, often repeated, it comes eventually to flow over all parts of its delta, building up each part in succession. By such a process the Colorado must have discharged alternately into the gulf and into the depression now known as the Salton Sink, meanwhile building up the delta

dam that separates them until it reached a height of about 40 feet above sea level. During this process it is highly probable that water filled the Salton depression and evaporated from it many times, for it must have quickly disappeared whenever the erratic river changed its course to the gulf, for the run-off from the mountains that surround the sink is too slight to maintain a permanent water body in this region of intense evaporation. Meanwhile the original body of salt water that occupied the sink had been displaced by the volumes of fresh water poured into it from the river, and in the intermediate stages of the lake's existence, at least, its water was fresh or nearly fresh. A clear and definite indication of the last occupancy of this depression by a lake, presumably just before the river had shifted to the course that it now follows to the gulf, may be seen in the remarkably well-preserved old water line that rims the desert from Indio to the Cerro Prieto at a height of 40 feet above sea level (Pls. III, *A*, IV, and V). On the rocky points that projected into the lake it is marked by a thick deposit of calcium carbonate (Pl. III, *A*), by slightly cut sea cliffs, and by a change in the profile of the rocky spurs at the water line. Where alluvial cones and the sandy floor of the desert formed the shore line, beaches have been developed, and although of soft sand, easily eroded, they are even now well preserved, thus testifying to the recency of the action that produced them. Over the floor of the desert and along the sandy beaches are myriads of shells of fresh or brackish water mollusks[a] that lived in the lake.

There are some reasons for thinking that the lake at this latest stage was not perfectly fresh—that its waters were at least distinctly "hard." Its area, when it stood at 40 feet above sea level, was somewhat in excess of 2,100 square miles. The average flow of the Colorado has been determined as about 11,000,000 acre feet per annum. The evaporation from a surface of the area of the old lake, under the conditions that prevail here, has never been determined, but is undoubtedly high. If it is as high as 8 feet per annum it would nearly equal the average annual inflow from the Colorado; if it is but 7 feet per annum the average inflow would exceed the evaporation by 2,000 second-feet, or somewhat less than 14 per cent of the inflow. In either event the waters of the lake would be markedly more alkaline after a term of years than those of the Colorado. The calcium carbonate incrustations (Pl. III, *A*) on the rocky points about the shores of the old lake are best explained by supposing that the lake waters contained large quantities of this salt, so that wherever they broke in spray and evaporated more rapidly than usual the carbonate was deposited. This necessary excess of inflow

[a] Stearns, Robt. E. C., Remarks on fossil shells from the Colorado Desert: Am. Naturalist, vol. 13, pp. 141-154.

THE "WATER LINE" ABOUT THE BASE OF A GRANITE OUTLIER SOUTHWEST OF COACHELLA.

over outflow at the period of maximum area of the lake, taken in connection with the thick calcium carbonate incrustations on the shores, indicates distinctly hard water. It may be assumed that other salts than calcium carbonate were also present in large amount, for the conditions that would lead to an abundance of the one salt would also lead to an abundance of the others. The shells so thickly distributed over the desert floor, however, are not salt-water forms, but are identical with those now found living in the springs and occasional permanent streams about the desert borders. Many of these springs and streams are somewhat brackish, and the creatures flourish in them. It seems probable, then, that the lake waters also were rather alkaline, perhaps even brackish, at the time when the lake attained its maximum area.

The period at which this lake disappeared can not be precisely fixed. The time units of geology are too large and too indefinite to translate satisfactorily into years, so that when we say that the disappearance of the lake is the most recent of geologic events we still leave the mind groping for a definite human standard of time. The sandy beaches which mark the borders of the ancient lake are cut away, to be sure, where washes cross them from the mountains, but in sheltered places they are still perfect. Where they stretch across an embayment from one rocky point to another they are mere embankments of sand, old barrier beaches, with depressions behind them once occupied by shallow lagoons. In other areas, where they contour the alluvial cones, they are gullied and cut away where streams have flowed across them, but in other places are preserved unscarred. At one locality noted a low sea cliff that had been cut in alluvial-fan material was still preserved, although the loose sand and bowlders would slump in a few heavy storms.

In a region of abundant rainfall such ephemeral forms as these would be more nearly obliterated within fifty years after the lake had disappeared than they now are in the desert. In such a region the precipitation is twenty times that of the desert. It is the crudest of estimates—merely a guess in fact—to state that, reasoning from geologic evidence alone, it may be a thousand years since the lake disappeared, yet it puts in concrete form such a guess as the geologist is able to make, and this guess may be correct within a margin of error of 50 per cent.

When human records are studied some evidence on this point is found, but it is almost as uncertain as to time as that furnished by the physical features. The Indians in the Coachella Valley have distinct legends to the effect that at some time in the past the valley was occupied by a large body of water. Professor Blake records that they told him of a time when a great water body existed in which

were many fish, and of the manner in which that water disappeared "poco á poco"—little by little—until the lake became dry.

The Indians now living in the desert put this event as far back as the lives of four or five very old men, say four or five centuries ago at the most. There are, of course, no records and there is no known check on this assertion. Statements by Indians as to time, beyond the limits spanned by their own memories, are notoriously inaccurate. Furthermore, we do not know the means used to procure this statement. The native races are usually very prone to follow the suggestions contained in leading questions, and so to give the answer desired by the questioner. To obtain an entirely independent and unguided answer is one of the most delicate of tasks. Yet their statement has some value, and combining the evidence of the physical conditions and the Indian legends, it may be said that it is probable that the lake disappeared and left the desert as we have known it in historical time, from five hundred to one thousand years ago.

THE DESERT FLOOR.

SLOPE OF FLOOR.

From this sketch of the origin of the desert it will be realized that the floor of the greater part of it for many miles north and south of the international boundary line is Colorado River delta, and that the grades of those portions of it now above the gulf level and originally above the level of Lake Cahuilla[a] are the grades that would be established by a river of the type of the Colorado, carrying the burden of silt which it carries, and are fairly uniform. The peculiar and—from the engineer's point of view—the most significant feature about the desert surface, however, is the steep grade of its northern slope from the old water line in the vicinity of the international boundary to the bottom of the Salton Sink.

From Yuma to the gulf, a distance of about 80 miles, there is a fall of 142 feet, uniformly distributed, while from Yuma to the bottom of the Salton depression is approximately 120 miles and the fall about 416 feet, but this fall is not uniformly distributed (Pl. I). The grade from Yuma to the gulf, therefore, is only about half of the average of that from Yuma to Salton, and throughout a part of the latter distance the difference is even greater; for example, from Sharps heading to the −250-foot contour north of Brawley the distance is

[a] The writer had proposed to call the ancient water body of which the Salton Sea is the successor "Blakes Sea," after Prof. Wm. P. Blake, who, as a result of his exploration of the Colorado Desert in 1853, explained so clearly and so satisfactorily the phenomena that exist there and their origin. The manuscript of this report was prepared in accordance with this intention, but before it was published Professor Blake had himself proposed the name Lake Cahuilla (Nat. Geog. Mag., vol. 18, p. 830). While I regret that the name of this honored pioneer in western geology can not be attached to one of his most striking discoveries, I realize that no other man has an equal right to name the now vanished water body, that the name is especially appropriate, and that it now has priority; therefore it is adopted here.

THE OLD WATER LINE AND THE NEW LAKE ABOVE FISH SPRINGS.

not over 50 miles and the fall is about 280 feet, or more than three times that from Yuma to the gulf.

This steep and irregular character of the northwest slope of the Colorado delta, as compared with its flat and relatively uniform southeast slope toward the gulf, is due entirely to the fact that the latter slope represents a stream grade determined under usual conditions, whereas the former is determined in part by the deposition of the silt in the still water of the lake that once existed there. The two slopes are therefore of entirely different origin and, of course, are of different grade.

This fact bears in two important ways on the problem of conducting Colorado River waters to the Imperial Valley for irrigation. In the first place it makes it easy to lead the waters in this direction, as it would not be were the grade no steeper toward the sink than toward the gulf; and in the second place it introduces an element of danger, because the northwestern course is so much more favorable than that toward the southwest, and it is always possible that during floods the stream may abandon its course to the gulf and adopt a new and more favorable one toward the sink. These possibilities and this danger have been illustrated in a startling way by the spectacular events of the last few years in the Imperial Valley.

DEVELOPMENT OF IMPERIAL CANAL SYSTEM.

In April, 1896, the California Development Company was organized by S. W. Ferguson, J. H. Beatty, H. Heber, and C. R. Rockwood to conduct water from Colorado River, at a point about 1¼ miles above the location since chosen for the site of the cement headgate to a point 14 miles away, on the Mexican side of the international boundary, where the channel of the Alamo was sufficiently well-defined to serve as a canal. It was planned to conduct the water along this channel through Mexican territory to the international boundary again 7 miles east of where Calexico now stands, and there to distribute it by means of a system of canals over lands in the United States.

Actual construction of the canal was begun about 100 yards above the international boundary in 1900, and was carried through to Calexico in June, 1901, when water was first delivered and irrigation begun. C. R. Rockwood, long a high officer in the company, estimates that there may have been 1,500 or 2,000 people in the Imperial Valley at that time, a large proportion of them in the employ of the California Development Company.

For three or four years after the first delivery of water to the lands colonization was rapid, the agricultural areas were extended, and what had been regarded as worthless desert was gradually reclaimed.

The fields of grain and alfalfa and the rows of trees, principally cottonwoods, which were planted completely altered the appearance of the country

INFLOW OF THE COLORADO.

During each low-water period after the completion of the canal some difficulty was encountered in getting water to flow freely through the canal just below the intake because of the silt that accumulated there. As the demand for water became greater with the increasing acreage under irrigation this difficulty was increased, and it was found necessary to cut, first a by-pass around the headgate at the intake, and then new intakes lower down, the dredges at hand being unable to keep the upper end of the original canal free from silt. It was intended that these additional cuts should be kept open only temporarily, in order to keep up the supply of water during the low-water period.

In October, 1904, the lowest intake, known as No. 3, was cut, in order to avoid a shortage of water during the period of low flow then on. Attempts were made to close it early in 1905, but high waters swept away the dams that were built, and the flood period of 1905 approached with this third intake still open. During this flood period the intake and the canal were greatly enlarged by the tremendous volume of Colorado River waters which flowed through the opening, and by the time the summer floods had subsided the entire Colorado had abandoned its normal channel to the gulf and was flowing westward and northward to Salton Sink by way of the channels of its old distributaries, Alamo and New rivers.

During this period the lake in the Salton depression grew rapidly, and the Southern Pacific Company was forced to build a succession of "shoo-fly" tracks, each higher than the last, in order to keep above the advancing waters and prevent interruption to traffic on its main line. The floods, too, had accomplished extensive destruction in the Imperial Valley, drowning many acres of valuable lands and destroying canals and farms near the flood channels (Pl. VI). It was realized, therefore, that the situation was grave, and preparations were made on a more extensive scale to control the river when the summer floods of 1905 should have passed.

A brush mat and piling dam, known as the Edinger dam, was begun in the autumn of 1905, but was swept away by the flood of November 30. An attempt was then made to extend a dam from an island opposite the intake to the west bank of the river, but high water swept this work away too. Constantly recurring floods during the spring of 1906 foiled all efforts to redivert the river, and during that period and the period of the summer floods the channels to the

A. NEW RIVER IN FLOOD NEAR THE FIVE HEADINGS.

B. A CHARACTERISTIC RECENT DRY ARROYO IN THE DESERT.

C. NEW RIVER IN FLOOD, NORTHWEST OF IMPERIAL, SUMMER OF 1905.

Salton Sink were deepened and widened, the destruction within the Imperial Valley was extended, and the lake grew and forced the Southern Pacific to rebuild at higher and higher levels.

When the summer of 1906 had passed with the river still beyond control, the California Development Company had reached the end of its financial resources, and all growth in the valley had ceased because of world-wide recognition of the menace to property interests which the uncontrolled condition of the Colorado meant. It was then felt that the only powers at hand capable of dealing with the situation were the Southern Pacific Railroad and the United States Government. The Southern Pacific made loans to the California Development Company to carry on its fight against the stream, and by means of its transportation facilities rendered additional essential aid. After the passage of the summer floods of 1906, the first attempt to control the river was the completion of the Rockwood gate, work upon which was begun the year before, but suspended in order that the plan realized in the building of the Edinger dam might be tried. With the failure of the Edinger dam and the approach of low water in the fall of 1906, the Rockwood gate was completed, but this, too, was carried out in the flood of October 11, 1906. A spur track was then built from the main Southern Pacific line at Hanlon Junction down the Colorado past the base of Pilot Knob; a trestle was built across the canal, which long since had been enlarged to the size of the original Colorado channel, and an attempt was made to check the stream by dumping into it, from flat cars, broken rock drawn from all the available quarries along the Southern Pacific line within several hundred miles. At the same time earth dikes were built parallel to the river for a number of miles above and below the dam, which came to be known as the Hind dam, in order to prevent the river from cutting around the structure when completed.

This effort was successful in November, 1906. The stream was turned from its course to the Salton Sea and forced into its old channel to the gulf, and it seemed that the end sought had at last been accomplished.

But on December 7, during a moderate flood following the closure, a breach was effected in the levee 2,500 feet below the dam, and in a short time this break had deepened and widened until the whole stream was again turned toward the sink.

The people of the Imperial Valley, the engineers in charge of the work, and the Southern Pacific officials whose immediate and prospective interests were seriously menaced were deeply discouraged by this turn in affairs. Money and effort had been freely expended. The struggle, at times apparently hopeless, had been long continued, and the longer the stream flowed toward the desert the more difficult

the problem became of controlling it, because, the grade toward the sink being approximately two and one-half times that toward the gulf, there was a well-marked tendency to scour out the bottom of the channel and thus to cut the new bed below the old one. This tendency was expressed in a most spectacular way by the extension through Calexico in July, 1906, of a fall of 40 feet or more in New River. This fall retreated upstream at an alarming rate, and at one time there was a serious and well-grounded fear that the entire canal system of the Imperial Valley would be left without a water supply by its extension to the Alamo channel above Sharps heading. In a final readjustment of grades by the river it was evident that the channel would be greatly deepened for many miles above Yuma, the Government dam at Laguna rendered impossible, and all agricultural interests along the lower course of the river destroyed, because the grade of the river would be lowered far below the canal intakes.

In the face of the repeated failures, the Southern Pacific seemed ready to abandon its attempt to close the canal, and appeal was made to the Government. The matter soon attracted national attention. An extensive correspondence was carried on between the President and Mr. E. H. Harriman, president of the Southern Pacific Company, and a special message dealing with the problem was sent to Congress. The Government had neither available funds, proper authority (the break was in Mexican territory), nor the equipment at hand for the prompt and vigorous action that was necessary to control the situation, and the railroad company, which had all of these, finally again undertook the work, the Government lending its engineers for consultation. The levee was practically reconstructed, broadened, made higher and extended downstream, and the same method was used to close the actual break that had proved successful when the Hind dam was built. Work was begun on this last project December 20, 1906, and the closure was completed February 11, 1907. Since then the work has withstood two summer seasons of high water, and there seems no reason why it should not prove permanent.

To safeguard the valley finally and completely, however, and to insure for it a regular water supply, further extensions of the levee system are necessary, and a more satisfactory method of dealing with the silt that the river carries must be worked out.

THE VALLEY DEPOSITS.

Classification of materials.—The evolution of the desert having been sketched and some of the events which are directly dependent upon its character as determined by that evolution having been pointed out, the nature of the materials which underlie it and the bearing of their character upon the problem of the occurrence of ground waters

may now be considered. The four classes of materials that make the floor of the desert valley in different parts are the delta silts, the consolidated clays and sandstones, the stream-deposited alluvium, and the wind-blown sands. A fifth class of deposit, of very small mass but of some commercial value—the saline deposits of the Salton marsh—should also be mentioned.

Delta silts.—The most important of these in mass is the body of silts and fine sands supplied by the Colorado and making up the whole of the delta lands, the greater part of the southern end of the Salton basin, and an important share of the northern end of the basin. Presumably the larger part of the total volume of these fine silts was deposited in still water, the gulf or the old lake. An important part, however, represents alluvial deposit from the overflow of the river waters. So fine are all of the materials that no important difference exists between those deposited in the gulf or the lake and those representing overflow or flood-plain deposits. They are all so fine grained as to be nearly impervious; that is, the pore spaces are so small that water circulates through them with extreme slowness. Their chief function in ground-water problems, therefore, is to serve as a barrier to percolation. Furthermore, within the delta proper they contain a notable amount of salts, so that the few springs which issue from them along the channels of New and Alamo rivers yield salty water, and the few experimental wells that have been put down in the Imperial Valley are dry or yield only a very small amount of salt water.

In the northern narrower end of the desert about Indio, Coachella, and Mecca, the material that fills the valley does not consist wholly of silts supplied by the Colorado, but of these intermingled with alluvium brought down by the intermittent streams from the surrounding mountains. The lake silts, or Colorado River silts, when thus interbedded with the coarser local material, perform the function of impervious confining strata, beneath which circulating waters accumulate under pressure. They are therefore important in bringing about the artesian conditions that prevail in this vicinity.

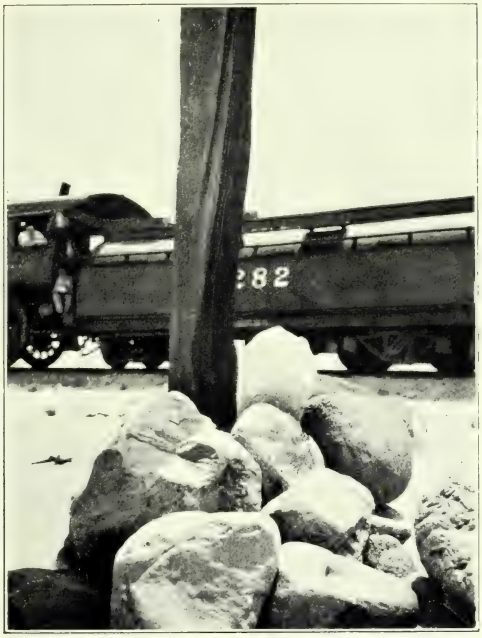
Consolidated Tertiary beds.—The floor of the west side of the valley from Signal Mountain northwestward to the base of the Santa Rosa Mountains is made up of Tertiary sandstones and clay beds, usually folded and in some places veneered with a covering of waste—sandy and gravelly alluvium. Near the valley axis, and especially below the old beach line, these beds are generally deeply buried beneath the valley filling, but toward the borders of the valley they stand higher and at many places they have been cut by erosion into fantastic badland forms. About ten years ago there was some excitement about oil in this region and a number of wells were drilled. These did not yield oil, but they served to test underground conditions.

The Yuha well, 6 miles north of the Mexican line and about 25 miles west of Calexico, was bored to a depth of about 1,200 feet. Salt water was found but no oil. Other wells like the Barrett, in Carrizo Creek valley, and the Hanna, at the north base of the Fish Creek Mountains, are dry holes, or obtained only salt water in the Tertiary beds. The Harper well, however, in the San Felipe Wash, at a reported depth of about 300 feet struck potable artesian water in the valley alluvium that overlies the Tertiary rocks.

Along the eastern border of the valley, as along the western, there is a fringe of Tertiary rocks, somewhat more extensively folded, as a rule, than those on the west, but bearing the same general relation to the valley. No wells have been drilled in these rocks so far as is known, but their character is such that waters of good quality need not be expected from them, although flowing waters might be obtained in some of the synclines. In the vicinity of Durmid, Bertram, Frink, and Imperial Junction these beds have been planed off and form a portion of the smooth, sloping, desert floor below the old beach line. Generally, however, along this eastern margin of the desert they are deeply eroded and form rough foothills along the base of the higher mountains to the east.

Sand dunes.—At certain seasons of the year strong winds blow toward the desert from San Gorgonio Pass and the mountains on either side of it. As these winds sweep down into the upper end of the desert they sift the sands from the alluvial material brought from the basins of the Whitewater, Mission Creek, Palm Canyon, and other streams, and carry them farther out into the desert basin. In this vicinity the effectiveness of the wind as a transporting agent is enormous. Professor Blake observed the effects of wind erosion here and figured examples of dense and resistant rocks deeply etched by the sand blast (Pl. VII, *B*). Since the Southern Pacific Railroad was built many other proofs of this action may be seen (Pl. VII, *A*). For example, the telegraph poles are worn away near the ground and have to be protected there by posts or rock piles. The more resistant knots or growth rings are brought into high relief by the etching of softer parts. The fish plates and bolts of the railway tracks are eroded rapidly, and the tin cans strewn along the track are kept bright and polished by the driving sand and are quickly etched through, as by acid, and worn away.

In the neighborhood of Indian Well there is a belt of sand dunes several miles long, but generally in this north end of the desert the phenomena are those of rapid removal rather than of even temporary accumulation as in dunes. As a result the desert floor is a sandy, rocky waste, with scant vegetation, and the air is full of dust, sand, and fine pebbles whenever the wind blows. But a very extensive sand dune area exists in the southeastern portion of the desert.



A. TELEGRAPH POLE NEAR PALM SPRINGS STATION DEEPLY CUT BY WIND-BLOWN SAND.

B. BOWLDER OF GNEISS NEAR PALM SPRINGS STATION, ETCHED BY WIND-BLOWN SAND.

From the vicinity of Mammoth station to a point a few miles south of the Mexican line, a distance of 40 or 50 miles, there is a continuous belt of dunes (Pl. VIII), from 2 to 6 or 8 miles wide.

An approaching sand storm in this region may always be seen while it is yet a long distance off, because the air is filled with dust to a height of several hundred feet. An estimate of the amount of material moved at such a time would be interesting, and though exact figures can not be obtained suggestive estimates are possible.

Saline deposits.—The bottom of the Salton depression before it was covered with water as a result of the inflow of the Colorado River was a salt-incrusted marsh. Within certain sections the salt crust was 6 inches or 1 foot thick, and sufficiently pure to permit it to be gathered in a commercial way and marketed at a good profit. The New Liverpool Salt Company undertook the commercial development of this marsh in the early eighties, and a profitable industry had been established when the inflow of water in 1904 put a stop to the work. In mining the salt the crust was removed and purified, and after a time was found to have been renewed.

The New Liverpool Salt Company sunk a well to a depth of somewhat more than 700 feet, and obtained flowing water under a pressure of 48 pounds per square inch. This water contained 1 per cent saline matter, thus proving the existence of salts at great depth in this depression. The managers of the salt company report that there is always water at or just below the level of the crust, and this in spite of the rapid evaporation there during the summer. Mr. Durbrow, for a number of years manager of the salt company, has testified to maximum evaporations of as much as $\frac{9}{16}$ inch in twenty-four hours in shallow pans during a period when maximum temperatures of 140° were reached. The water thus constantly carried into the air by evaporation must be replaced from underground sources, because surface inflow normally is slight and comes at very irregular intervals. The artesian pressures proved by the drilling of the salt company's well, by the numerous flowing wells farther north in the desert, and by the springs at Figtree John's, Alamo Bonito, and Agua Dulce, indicate that there is constant seepage toward the surface. The bottom of the sink has been an evaporating pan for a long period. From the time when this depression was first separated from the gulf by the extension of the delta dam from Yuma to the Cocopas, it has probably been filled by inflow from the Colorado and emptied by evaporation many times. During all of this time, also, it has been shoaling slowly because of accumulating wash and silt. Whenever the depression has been occupied by a lake, more or less silt has been deposited from the waters. In dry periods occasional heavy rain storms in the desert result in an inwash of materials from its borders. The muds thus deposited in

the bottom of the sink have contained definite though minute quantities of salts, and thus saline matter has accumulated there.

Probably the most abundant source of salts is the underground water that percolates slowly toward the basin from the northwest. This is of exceptional purity, as is shown by analyses of water from wells at Indio and Coachella, but like all natural waters it contains a small percentage of salts, and all of this is left behind as the water evaporates from the surface of the salina.

Since the ground waters rise at other points than in the very bottom of the valley, salts are found at the surface in many areas outside the Salton Sink. Indeed, wherever the ground-water level is so near the surface that the processes of evaporation and capillarity are sufficiently powerful to draw them quite to the surface, alkalies will inevitably accumulate, their amount depending on the rapidity of the process. When salts have accumulated at the surface all storms of sufficient magnitude to give surface streams into the sink carry a portion of these salts with them and assist in their concentration there.

WATER RESOURCES.

RAINFALL AND DRAINAGE.

The region north and east of Indio has not been mapped with sufficient accuracy to enable us to make a close estimate of the drainage area tributary to the Coachella valley; but a rough estimate, based on fairly accurate maps of the south and west limits of the valley and on much less accurate data in other directions leads to the conclusion that the drainage basins whose surplus waters escape to the Salton Sea from the northwest have a combined area of about 2,000 square miles. Probably 20 per cent of this total has a rainfall of from 5 to 25 inches per annum. The following tables comprise records of rainfall at Palm Springs (1889–1905), Indio (1878–1905), and Yuma, Ariz. (1884–1905):

EASTERN BORDER OF SAND DUNE AREA WEST OF MAMMOTH STATION.

Rainfall records.

AT PALM SPRINGS, CAL.

Year.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	Rainfall for season.
1889	.....	.....	.....	.....	.....	.....	0.30	0.06	1.54	0.00	0.01	0.00	1.91
1889–90	0.00	0.07	0.00	0.53	0.00	4.64	.52	.10	.00	.00	.00	.00	5.86
1890–91	.00	.25	.38	.00	.00	.50	.00	7.44	.00	.00	.00	.00	8.57
1891–92	.03	1.02	.10	.00	.00	.23	2.18	.26	.05	.00	.12	.00	3.99
1892–93	.00	.00	.00	.00	.00	.00	.40	.00	1.18	.00	.10	.00	1.68
1893–94	.35	.40	.10	.00	3.00	.11	.00	.00	.00	.00	.00	.00	3.96
1894–95	.00	.00	.00	.00	.00	4.25	3.50	.00	.00	.00	.00	.00	7.75
1895–96	.00	.00	.00	.00	.00	3.50	.00	.00	.81	.03	.00	.00	4.34
1896–97	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1897–98	.00	.00	.00	.00	.00	1.09	.00	.00	.60	.00	T.	.00	1.69
1898–99	.00	.00	.00	.00	.00	.70	1.21	.12	.00	.00	.00	.00	2.03
1899–1900	.00	.62	T.	.00	.50	2.86	.80	.00	.00	.00	.00	.00	4.78
1900–1901	T.	.00	.00	1.29	T.	.00	T.	3.50	.00	.00	.00	.00	4.79
1901–2	.00	.00	.00	.00	.00	.00	.50	.00	.50	.50	.00	.00	1.50
1902–3	.00	.00	.00	.00	.70	.70	.00	.00	.70	.00	.00	.00	2.10
1903–4	.00	.00	.00	.00	.00	.00	T.	T.	.....	.00	.00	.00	T.
1904–5	.00	1.00	.00	.10	T.	.00	2.16	3.95	1.66	T.	.48	.00	9.35

Average for 16 years, 3.90 inches.

AT INDIO, CAL.

1878	.....	.....	.....	.....	.....	.....	0.10	0.00	0.00	0.00	0.00	0.00	0.10
1878–79	0.00	0.00	0.00	0.00	0.00	1.00	.60	.30	.00	.00	.00	.00	1.90
1879–80	.00	.00	.00	.00	.40	.00	.00	.00	.00	.00	.00	.00	.40
1880–81	.00	.00	.00	.00	.00	.70	3.45	.00	.50	.00	.00	.00	4.65
1881–82	.00	.00	.00	.00	.00	.00	1.50	.00	.00	.00	.00	.00	1.50
1882–83	.00	.00	.00	.00	1.00	.00	.80	1.13	.11	.00	.00	.00	2.43
1883–84	.00	.00	.00	.06	.00	.86	.00	3.16	.62	.44	.46	.00	5.60
1884–85	.00	.00	.00	.00	.00	.70	.00	.00	.00	.10	.00	.00	.80
1885–86	.00	.00	.00	.00	.90	.00	.00	.00	.00	.00	.00	.00	.90
1886–87	.00	.00	.00	.00	.12	.00	.00	.93	.00	.30	.00	.00	1.35
1887–88	.00	T.	.05	.15	.00	.00	.75	.00	.00	.00	.00	.00	.95
1888–89	.00	.00	.00	.00	1.10	1.11	.57	.00	1.05	.00	.00	.00	3.83
1889–90	.00	.95	.00	.60	.01	3.29	.65	.06	.00	.00	.00	.00	5.56
1890–91	.00	.10	.20	.00	.00	.22	.00	1.90	.00	.00	.00	.00	2.42
1891–92	.00	1.16	.00	.00	.00	.25	2.00	.43	.22	.04	.14	.00	4.24
1892–93	.00	.00	.00	.00	.00	.00	.03	.00	1.60	.00	.00	.00	1.63
1893–94	.05	.75	.07	.00	.14	T.	.00	.00	.00	.00	.00	.00	1.01
1894–95	T.	.00	.00	.00	.00	.00	6.01	.00	.00	.00	.00	T.	6.01
1895–96	.00	.00	.00	.00	.00	.00	.92	.00	.00	.00	.00	.00	.92
1896–97	.00	.00	.00	.00	.00	.00	1.10	.19	.00	.00	.00	.00	1.29
1897–98	.00	.00	2.10	.00	.00	.00	.10	.00	.30	.00	.00	.00	2.50
1898–99	.00	.30	.00	.00	.00	1.00	.40	.00	.00	.00	.00	.00	1.70
1899–1900	.00	.00	.10	.00	.60	.20	1.00	.00	.30	.15	T.	.00	2.35
1900–1901	.00	.00	.08	1.04	.17	.06	.29	1.46	.00	.00	.00	.00	3.04
1901–2	.00	.00	.00	.00	.00	.40	.20	.00	.00	.00	.00	.00	.60
1902–3[a]	.10	.00	.00	.00	.50	.80	.00	.00	.....	.75	.00	.00	2.15
1903–4[a]	.00	.10	.12	.00	.00	.....	.....	.....	.....	.00	T.	.00	.22
1904–5	.00	.33	.00	.00	.....	.....	2.16	3.95	1.66	T.	.48	.00	8.58

Average for 25 years, 2.65 inches.

[a] Broken record.

AT YUMA, ARIZ.

1884	.....	.....	.....	.....	.....	.....	T.	1.58	1.48	0.07	0.44	T.	3.57
1884–85	0.01	0.32	T.	T.	T.	1.96	.....	.02	.....	.07	.....	0.00	2.38
1885–86	.05	.86	0.00	0.00	1.71	.01	1.06	.08	.33	.31	.00	.00	4.41
1886–87	T.	2.23	.00	1.11	.23	.00	.00	T.	.00	.20	T.	.01	3.78
1887–88	T.	T.	1.09	.02	2.43	.15	.18	.05	.05	T.	.00	.00	3.97
1888–89	.04	T.	.01	.99	.68	.95	1.12	.06	.24	.00	.00	T.	4.09
1889–90	T.	.25	.00	.59	T.	2.43	.08	.11	.06	.53	T.	.00	4.05
1890–91	.02	T.	.....	T.	T.	.00	.00	2.53	T.	.00	T.	.00	2.55
1891–92	.04	.05	T.	.00	.00	.05	1.85	.87	.52	T.	.05	.00	3.43
1892–93	.00	.02	.04	.00	.00	T.	T.	.....	1.53	.00	.31	.00	1.90
1893–94	.40	.42	.30	.00	.30	.11	.00	.00	.00	.00	T.	.00	1.53
1894–95	.30	.01	.12	1.25	.00	.29	.78	.02	T.	.00	.00	T.	2.77
1895–96	.01	T.	T.	.15	.37	.00	.14	.00	.43	T.	T.	.00	1.10
1896–97	.41	.32	.31	.10	.06	.78	2.83	.06	.48	T.	T.	.00	5.35
1897–98	T.	.57	.20	T.	.00	.04	.42	.00	.39	.01	.00	T.	1.63
1898–99	.00	.19	.....	.00	.21	1.16	.....	.01	T.	.00	T.	T.	1.57
1899–1900	T.	.06	.00	.02	.50	.....	.08	.11	.06	.53	T.	.00	1.36
1900–1901	.02	T.	.....	(?)	T.	.00	.12	3.01	.30	T.	T.	.00	3.45
1901–2	T.	.22	.00	T.	.00	.00	.26	T.	.21	.00	.00	T.	.69
1902–3	.11	T.	T.	.00	.57	.78	T.	.23	T.	T.	.00	.00	1.69
1903–4	.04	T.	.67	.04	.00	T.	.00	T.	.28	T.	.07	.00	1.10
1904–5	.05	.69	.24	T.	.....	.10	1.15	3.43	3.33	.16	.00	.00	9.15

Average for 21 years, 2.95 inches.

The more effective portion of the tributary drainage area includes the eastern slope of San Jacinto Peak and the southern and eastern slopes of the San Gorgonio Mountain mass. From these mountains small perennial streams flow into the northern end of the desert. The largest of these is Whitewater River, which rises on the eastern slopes of San Gorgonio Peak. At the foot of San Gorgonio Pass its waters are divided, one portion being utilized for irrigation in the vicinity of Whitewater station, while another portion, at one time used for irrigation at Palm Springs, is allowed to waste into the desert.

From Palm Canyon also a perennial stream flows, and Tahquitz Creek and other minor streams which rise on San Jacinto Peak furnish small amounts of water to the neighboring portions of the desert.

Over the remaining 80 per cent of the desert ranges whose slopes are in the direction of the Coachella Valley, the precipitation is extremely meager. At Indio it averages about 2.65 inches per year, and is probably but little more on the desert ranges to the east. A somewhat larger amount, which increases with the altitude, falls on the northern slopes of the Santa Rosa Mountains, because these are higher and receive some share of the moisture that is borne eastward by the Pacific winds.

Much of the rainfall in the desert comes in heavy storms of short duration, and since the slopes on which it falls are free from vegetation and have but little soil covering, the proportion of run-off is large—much larger than in more humid and better forested areas. But as the desert air is intensely dry, the immediate loss by evaporation must be a large proportion of the total fall.

At the base of each mountain range, where great alluvial fans containing much coarse material are piled up, such flood waters as reach them are promptly absorbed. Hence, in spite of the intense heat of the long summer, and the unfavorable situation of the valley in regard to rainfall, the large tributary drainage area must result in a considerable aggregate annual contribution to the underground supply. It is not possible, however, to make any definite estimate of its amount.

East and west of the southern end of the desert—the Imperial Valley—are arid ranges like those that inclose the Coachella Valley, except that they are not so high and not so effective as rain makers. Furthermore, this south end of the desert is much wider than its northern end, and the very slight and uncertain run-off from its bordering mountains does not reach the heart of the basin. On the other hand, a portion of the overflow from the annual summer floods of the Colorado occasionally extended down into the valley before irrigation began there. Sloughs of fresh water were thus occasionally

found along the channels of New and Alamo rivers, and intermittent water basins like Cameron Lake, Blue Lake, and Mesquite Lake were sometimes filled by these flood waters. Farther south, in Mexico, in the vicinity of Volcano Lake, which is near the divide between the Salton Basin and the Gulf of California, flooding during the summer high-water period in the Colorado is usual instead of rare. Indeed, this part of the desert, which for years has been used as a cattle range, owes all of its value for this purpose to the natural irrigation that it receives during the summer floods in the river.

UNDERGROUND WATERS.

LIMITS OF ORIGIN.

The geologic conditions within and about the borders of the desert preclude the possibility of its ground waters originating in drainage basins beyond the surrounding mountains. These ranges are formed of granitic and metamorphic rocks, practically impervious to water, 50 or 100 miles through, and extending indefinitely downward. It is impossible to conceive that water circulates through them in any valuable quantity. It has also been suggested that these waters may be derived from Colorado River, not by percolation through the separating mountain ranges but by subsurface flow around the southern point of these ranges through the sands and silts of the valley.

A consideration of the distribution of temperatures and of the character of the waters over the Coachella Valley is sufficient to show that the supply does not come from the southeast. The average temperature of well waters near the northwest end of the area in which developments have taken place is about equal to the mean annual temperature of the region—72°. Nearer the Salton Sink the temperatures of waters are higher. Here the springs or shallower wells have temperatures of 75°, 80°, and 90°.

An experimental well has been sunk in the very bottom of the Salton basin by the company that mined salt there before the inundation, and a flow of water with 1 per cent saline matter and a temperature of 92° was obtained at a depth of 500 feet.

Other saline and sulphuretted waters were found in wells, now submerged, in the vicinity of Mortmere, and the springs southeast of Figtree John's are saline, sulphuretted, or carbonated.

Below the Salton Basin, 5 or 6 miles south of Lano station, in an area now submerged, there was a group of boiling mud springs. The waters that rose here were not potable; some were acidulated and some had temperatures of 212°. Furthermore, in the vicinity there are the remnants of old volcanoes. It is wholly unlikely that Colorado River waters percolate eastward through areas in which highly mineralized and highly heated waters of the types just mentioned exist. This is particularly true because the normal waters of Indio and vicinity are of great purity. That they contain but 15 to 25

parts of solid matter per 100,000 parts of water is shown by the following analyses:

Analyses of Colorado desert waters.

[Analysts, G. E. Colby and M. E. Jaffa, University of California.]

[Parts per 100,000.]

	1. From surface-water well 20 feet deep, one-half mile northeast of Indio station.	2. From water strata 120 feet deep, one-half mile northeast of Indio.	3. From reservoir at Coachella.	4. From artesian strata 500 feet deep at Coachella.	5. From surface well 25 feet deep, one-half mile north of Coachella.
Sodium and potassium sulphates, etc	4.3	4.3	4.92	6.3	3.80
Sodium chloride (common salt)	1.12	.20	.18	.20	.10
Sodium carbonate (sal soda)	2.1	2.10	6.40	4.30	5.30
Calcium and magnesium carbonates, etc Calcium sulphate (gypsum)	7.0	6.8	1.10	3.00	7.80
Silica	4.0	4.0	1.00	1.00	2.00
Organic matter and chemically combined water	.40	.40	1.40	1.12	6.60
	18.00	17.8	15.00	16.00	25.60

All the water clear, colorless, odorless, and tasteless.

An additional proof of the dependence of the Indio underground supply upon local rainfall was furnished by the prompt response of the wells to the exceptional rainfall in the winter of 1904–5. Wells whose yield had been noticeably affected by the developments of the preceding four years were restored to approximately their original flow by that seasons's rains. Such a response could not occur if the Colorado River were the source of the waters.

These arguments add strength to the inherent improbability, amounting practically to a certainty, that waters in any valuable quantity percolate through the 100 miles or more of close-textured Colorado River silts that lie between Yuma and Indio. It must therefore be concluded that these waters enter through the alluvial material that occupies the borders of the valley, especially near its northern end, where the water supply is greatest, and move thence slowly toward the center of the basin. It is these waters in slow motion toward the Salton Sink that are intercepted by the 400 wells of the Coachella Valley.

The physical conditions which control the movements of the underground waters may be readily inferred from the character of the deposits that fill the valley. Except about the borders these deposits are fine. This follows directly from the fact that they are in part lake sediments and in part the outer edges of alluvial fans. Well drillers in the valley are able to sink wells to depths of 600 or 800 feet by the hydraulic method, which can be used only where no coarse material is encountered (fig. 2). The strata which they pierce are alternating layers of clay and sand with occasional streaks of very fine gravel. This alternation of fine and coarse material (fig. 3), which is essential to artesian conditions, exists presumably only in the northern end of the desert. Few bowlders are encountered (fig. 4), and these are about the borders of the

A. GROUP OF ACTIVE MUD VOLCANOES WEST OF IMPERIAL JUNCTION.

B. GENERAL VIEW OF QUIESCENT MUD VOLCANOES NEAR IMPERIAL JUNCTION.

basin, where their source may usually be recognized in a near-by canyon. South of Salton Sink, where the original lake was larger and the material with which it was filled was supplied more directly

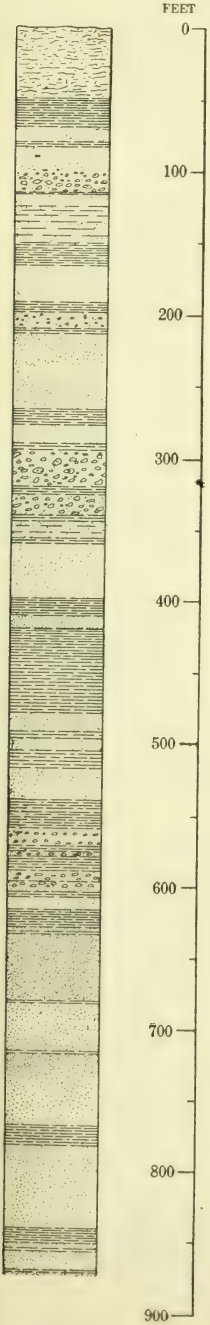


FIG. 2.—Section of Southern Pacific well at Indio, Cal.

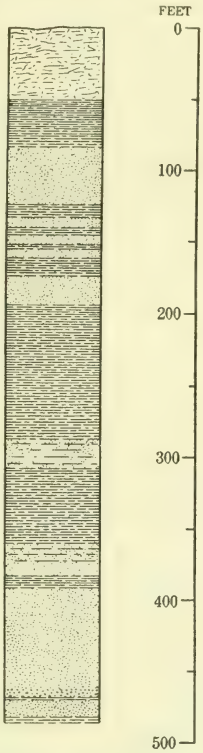


FIG. 3.—Section of Southern Pacific well at Mecca, Cal.

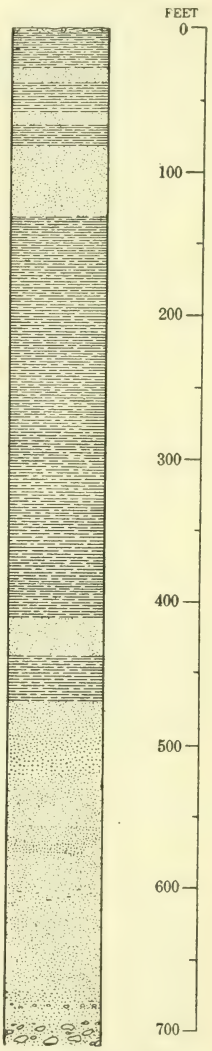


FIG. 4.—Section of Southern Pacific well at Mortmere, Cal.

by the distant Colorado River, the coarser strata are much more rare. Drill records here reveal a comparatively uniform series of fine sediments through which the circulation of waters in sufficient amounts to give artesian pressures is scarcely possible. Two or three deep wells have been drilled near Imperial, but no flow was obtained, and the water found in limited quantity was too saline to be usable. The northern limit of these nonartesian conditions can not be predicted closely. North of the southern end of the old Salton marsh, however, flowing waters will be found, although for a number of miles they will not be suitable either for drinking purposes or for irrigation; but south of this limit artesian waters of any quality need not be expected, except perhaps in small areas near the mouths of the larger canyons where local conditions may be favorable. The Harper well, near the San Felipe wash, drilled for oil but yielding flowing water, is a case in point.

A matter of more importance to the irrigator than the theoretical limits of the artesian basin is the limit of the usable waters. This can not be determined theoretically; but the waters developed by wells drilled near the old Mortmere switch, and the position and character of some of the natural springs, indicate that ground waters sufficiently pure and in sufficient quantity to be used for irrigation may be found northwest of a line crossing the valley from the southern end of the Santa Rosa Mountains to the vicinity of Salton Station; southeast of this line the waters are distinctly saline. The heavy incrustations of surface alkalies which occupy the center of the valley for a number of miles northwest of this limit of usable waters, and preclude the use of the land for agricultural purposes, will probably be more potent than the character of the waters in checking development toward the southeast.

SOURCE AND CHARACTER OF THE UNDERGROUND SUPPLY.

The only source of the underground waters of this region is the rainfall on the desert and the surrounding mountains. It has frequently been suggested that distant and less obvious sources might supply the waters that seem to irrigators within the Coachella Valley too abundant to be due entirely to run-off from the desert ranges about them. A similar opinion is commonly held in artesian areas, because proper value is not given to the importance of the time element in the accumulation of underground waters. The waters that are being developed in the Coachella Valley have slowly accumulated there throughout a long period. The amount annually added to them is but a small percentage of the total supply. Before irrigation was begun this annual increment served simply to balance the amount annually reaching the surface by capillarity and artesian pressure and there evaporating; for with the land surface in

the Salton Sink 273 feet below sea level, and a great body of nearly impervious silts intervening, there can be little if any escape of desert waters toward the gulf by percolation. Irrigation, through the boring of artesian wells, probably somewhat reduces this natural loss in the lowest parts of the area, because it reduces artesian pressure; but it substitutes a greater loss from the irrigated surface and from locally raised water tables.

PRESENT DEVELOPMENT AND CONTROLLING CONDITIONS.

In April, 1905, the amount of water developed by the artesian and pumped wells in the Indio basin during the irrigating season was about 100 second-feet, an amount equivalent to a continuous flow of about 20 or 25 second-feet maintained throughout the year. Impressive estimates of the total amount of water stored in the desert might be made, since it has an area of at least 400 square miles above Salton Sink and the depth of the saturated sands over this area probably averages more than 1,000 feet. Such an estimate, however, can have little value, not only because it is based upon many unknown factors, but also because the amount of water which may be taken from a basin depends not on the total amount stored there but on the amount annually added. This amount is necessarily much smaller for the desert than in the more humid area to the north, known as the valley of southern California, and even there, where the amount of water annually available for a recharge of the underground reservoirs is many times what it is in the Indio region, the artesian areas have shrunk 35 per cent in the past ten or twelve years as a result of intense development.

The effect of the development for irrigation upon the flow of the wells in the Indio region, particularly about the upper part of the basin, had been marked previous to the winter of 1904–5. The exceptional rainfall during that winter, however, amounting to 8.58 inches at Indio, where the average is but 2.65 inches, is reported by the well owners to have practically restored the yield of the wells to its original amount. A repetition of such exceptional weather conditions, however, is not to be expected often, so it is desirable to consider the usual effect of the present development.

The accompanying table has been prepared to show the actual condition of a few of the wells at two periods separated by an interval of two years. The first measurements were made in April, 1905, and the second in April, 1907. This list includes 36 wells distributed from Agua Dulce to Indio and represents therefore all parts of the basin. In nearly every well the water plane has lowered or the yield has lessened. In a few wells the change has been very slight; in others it has been marked. In some of the wells that two years ago were flowing freely the water now stands several feet below the surface.

Comparative records of wells.

Number.	Owner	April, 1905.		April, 1907.	
		Flow.	Distance to water.	Flow.	Distance to water.
		Inches.	*Feet.*	*Inches.*	*Feet.*
6	A. L. Gordon & Bro.	a 12			1½
7	J. W. Newman	a 5			10
9	S. B. Twomey	a 15		7	
10	J. T. King	a 15		7	
11	C. B. Bisbee	a 8		2	
13	W. H. Mather	a 15		a10	
15	E. D. Morrill	a 25		a15	
16	do	a 25		a15	
17	J. K. Ross		6		11
18	do		8		12
41	N. O. Nelson		b 16 12		
42	do		b 15 14		21
43	do		b 16 18		20
44	do		b 16 18		20
45	do		b 17 18		20
46	C. A. Hayott		b 13 18		
50	Will Everett		12		16
51	do		9		13
52	do		9		14
74 75	Toro Indian Reserve	a 25		20	
78	D. Bond	a14		13	
92	Mrs. S. A. Williams	a10		8	
128	F. A. Leap	23		4	
132	R. B. Thayer	26		7	
133	E. N. Stanley	33		11	
144	Town of Coachella	a 4		1	
160	Mr. Teagle		22		23½
171	A. W. Haight	5			4
182	W. I. Hobbs	21		7	
183	do	a 8		4	
222	O. C. Eberhardt	7		2	
223	do	11		2	
244	Stanley and Payne	a 7		5	
255	Martin and Moore	11		2	
261	G. L. Keith	20		10	
279	Peters, Evans & Gage	8		5	

a Estimated flow. b January 3, 1905.

NEED OF CONSERVATION.

The continued drilling and use of wells in an artesian region diminish the area in which the wells will flow, and those about its borders that are least favorably located decrease in yield or cease to flow, so that to maintain the water supply it becomes necessary to install pumping plants. This stage has already begun in the Coachella Valley, and it will undoubtedly extend over larger areas about the northern end of the artesian belt. The gravity of the condition will depend largely on the extent of future developments and on the care with which wells that are now flowing are managed. The unlimited drilling of wells in the lower, most favorably situated portions of the valley will hasten the depletion of the supplies in the higher, less favorably situated areas, and the use of pumping plants will quickly influence the yield of adjacent flowing wells.

The practice of leaving strong wells uncapped when the water is not needed can not be too strongly condemned. This waste of the water not only depletes the underground reservoirs but injures the

A. A DESERT HOMESTEAD SOUTH OF INDIO.

B. EARTHEN RESERVOIR NEAR INDIO.

C. COTTONWOODS, 2 TO 4 YEARS OLD, NEAR COACHELLA, CAL.

soil over which it flows, because when the flow of water is not controlled and properly distributed the greater portion of it is evaporated from the surface, bringing about the concentration of alkali there. The greatest damage, however, results from the needless tax on the deep basins. The supply in this region will necessarily be sensitive, because the amount annually added to it by rainfall is small. A strong public sentiment, therefore, should be created, which will under all circumstances oppose the careless use of artesian wells. It should be insisted that the man who wastes or uses needlessly a product on whose abundance the prosperity of the section depends is his own and his neighbor's worst enemy. Although ranch owners generally in this section realize the need of care in this respect, there are a few important exceptions, on whom the pressure of public opinion should be brought to bear.

In addition to this obvious and useless waste there is other waste through poorly developed irrigation methods and poorly constructed reservoirs and ditches. This is a condition that is almost inevitable in new communities. Better irrigation practice comes only at a later stage, when the value of lands has been thoroughly established and agricultural habits have become fixed. It is probable that the amount of water now developed, if it could be utilized without waste, could be made to irrigate 50 to 100 per cent more land than at present.

FUTURE OF THE WATER SUPPLY.

Now, while it is obvious that additional development or even the maintenance of the present development will cause a gradual shrinkage in the artesian zone and a gradual expansion of the pumping zone—because additional development means increased drainage of the underground reservoirs by artificial means—it is nevertheless probable that the highest possible use of the underground waters will not have been reached until further developments have been carried out. There is a continuous slow movement of these subterranean waters beneath the Indio region toward the southeast, but the water does not escape to the gulf. Much the greater part of the subsurface percolation probably reaches the surface eventually in the vicinity of the Salton Sea, and before the inflow of the Colorado it escaped into the air by evaporation. A loss takes place in this manner wherever the water table stands so near the land surface that capillarity becomes effective. This condition originally prevailed over the entire area of the Salton Sink and now exists over many square miles about the lower part of the Coachella Valley above the borders of the Salton Sea. Whatever reduces artesian pressure reduces the leakage of the ground waters in this way and so decreases loss. Hence the development of artesian waters has some slight effect in lessening the proportion that is lost under natural conditions, and correspondingly increases the proportion available for man's use.

It is believed that while slow decline of artesian pressure will necessarily take place in the Indio basin, this decline need not be especially harmful to the agricultural interests of the valley for many years to come, even although twice the amount of water now developed is procured, and it is also believed that by a proper utilization of the waters now developed and those to be developed in the future several times the acreage at present under cultivation in the valley may become productive without too great drafts on the supply.

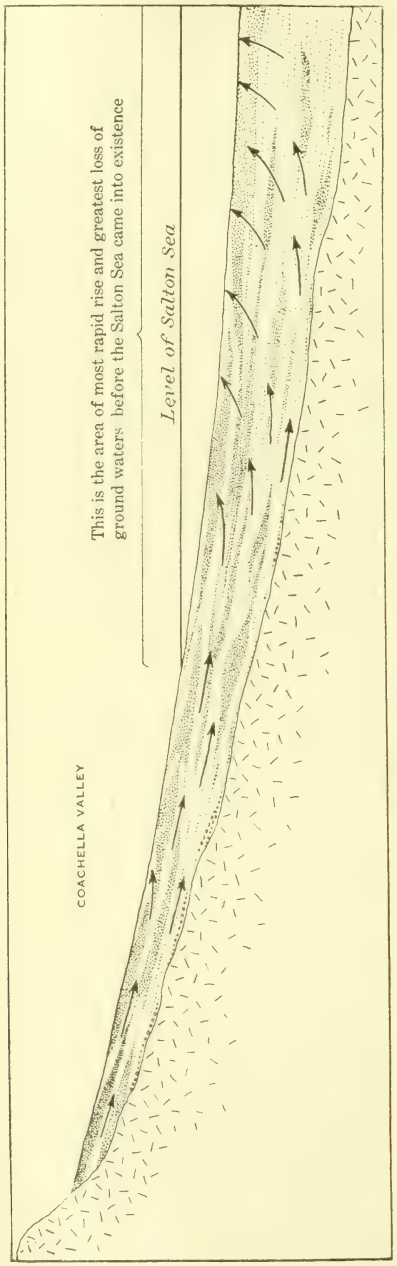

This is the area of most rapid rise and greatest loss of ground waters before the Salton Sea came into existence
Level of Salton Sea
COACHELLA VALLEY

FIG. 5.—Diagrammatic section illustrating course of ground waters through Coachella Valley.

Pumped waters will become increasingly important and will be relied upon more and more as time passes. Abundant water for pumping may be obtained at depths of 100 to 200 or 300 feet, while much deeper wells must be bored over the greater part of the area to obtain an artesian supply. Furthermore, pumped waters are used more carefully than artesian waters. Human nature can not be trusted to value or to manage well that which costs little. Therefore, artesian waters will be wasted and pumped waters will be used with care in the same area. The cheapness of gasoline and crude oil and the efficiency of engines that utilize these fuels will make their application in irrigation more and more feasible as development continues.

EFFECT OF THE FILLING OF THE SALTON BASIN.

When development began in the Coachella Valley the bottom of the Salton Sink was a salt marsh—a huge evaporating pan from whose surface many thousands of tons of water must have passed

into the air annually from underground sources. In the spring of 1907 this basin was partially filled by a sheet of water covering an area of nearly 500 square miles and having a maximum depth of about 75 feet. A little consideration makes it evident that the existence of this water body must have a marked effect on the natural waste into the air of the subterranean supplies.

It is to be remembered, in the first place, that a certain analogy may be drawn between the underground flow of the Indio basin and the flow of a surface stream, although the analogy is not close at some points. Just as a surface stream has its source, its mid course, and its mouth or point of discharge, so has this body of ground waters a source, a mid course, and a point of discharge. Its source is in the alluvial fans, particularly their upper portions, where the surface waters sink and join the underflow. Its mid course is the Coachella Valley, through which the ground waters percolate slowly southeastward, in the direction of the general slope of the surface and presumably of the valley bottom, although its attitude must remain conjectural. The point of discharge of the ground waters is the Salton Sink, and indeed all the moist and practically all the alkaline areas about its borders.

Instead of discharging into a larger water body, as do surface streams generally, the ground waters discharge into the air by evaporation from the moist lands (fig. 5), a very minor part, of course, escaping through the springs that are found in the lower parts of the desert.

This escape is effected as a result of the hydraulic head of the ground waters and their constant tendency to rise as a consequence of this head, and, when they are near enough to the surface for it to act, as a consequence of capillarity also. The waters are removed by evaporation as quickly as they approach the surface. With this condition in mind, the effect of the water body in the Salton depression at once becomes apparent. It acts on the underground waters much as a dam across its mouth would act upon a river. A great part of the field from which the ground waters evaporated is covered by the lake and evaporation therefrom is prevented; and a part of the hydraulic head under whose influence the ground waters rose to the surface is balanced by the pressure of the lake waters, and this rise of ground waters is thereby interfered with (fig. 5). Very much less of the water of the Coachella Valley must be wasting now through evaporation than before the creation of the Salton Sea. No quantitative estimate can be made of this effect. It can only be said that it must be sufficiently powerful to be beneficial to the users of ground water in the Indio region.

This beneficial condition is necessarily temporary, as the Salton Sea is temporary. If the engineering work done and to be done about the intake of the Imperial Canal accomplishes its purpose of

preventing further inflow of the Colorado, the Salton Sea will probably have nearly disappeared by 1925; and as it gradually shrinks a larger and larger area will be exposed, through which ground waters will escape by capillarity and evaporation, until, with the disappearance of the sea, the conditions that prevailed before it came into existence will have been restored. From the point of view of the users of ground waters in the Coachella Valley, it is to be regretted that the sea can not be maintained at its present level.

HISTORY OF DEVELOPMENT OF THE INDIO REGION.

In the Colorado Desert railroad building was encouraged by the Government in the same way as in other parts of the West—that is, every odd section of public lands for a number of miles on either side of its right of way was deeded to the railroad on condition that it should construct its line. Thus one-half of the lands in the Coachella Valley belong to the Southern Pacific. The railroad has disposed of a few sections near its track, but it still holds the greater part of the original grant, and agricultural development is therefore confined chiefly to the even sections.

The larger portion of these public lands were filed upon under the desert land act in 1885 and 1886. After the completion of the successful deep well at Walters in 1894, proving finally the presence of abundant artesian waters beneath this part of the desert, interest in the possibility of its reclamation was greatly stimulated, but the great cost of drilling wells by the ordinary method prevented further extensive development until 1900. In April of that year the first successful hydraulic well was put down at Indio. It reached a depth of 500 feet in seventeen hours, and the cost was comparatively nominal. From the date of its completion until the present development has been continuous, and now from 350 to 400 deep wells are scattered about over those parts of the desert which are accessible from the stations between Indio and Salton Sea. Of this number, from 250 to 300 are artesian. About 90 pumping plants have been installed, two or three wells frequently being coupled together and pumped from one station.

It is estimated that more than $100,000 is invested in the artesian wells that have been bored in the valley, and that the pumping plants with the wells on which they are installed represent an additional expenditure of $75,000. If the cost of reservoirs and of such pipe lines as have been put in are added, it will easily bring the total investment in works for the development and distribution of water to $200,000.

By the use of the waters which have been developed in this way, 4,000 or 5,000 acres of land have been reclaimed and are successfully irrigated. The area in which flowing waters may be pro-

VIEW OF THE SALTON BASIN FROM THE WEST SIDE AFTER THE INFLOW OF THE COLORADO.

cured—it has been roughly outlined by the developments to date—covers approximately 140 square miles. This area extends from a point a short distance above Indio to a point below the present border of the Salton Sea. The greater part of it lies on the south side of the Southern Pacific Railway, but there is a strip from 1 to 2 miles wide on the north side of the line.

Much the stronger artesian flows are obtained at the lower elevations near the southern end of the belt. Wells at the upper or northwestern extremity of the valley give inferior yields, so that it has been found necessary to pump from many of them in order to obtain sufficient water for successful irrigation. This condition is due in part to the originally inferior yield of these higher wells and in part to a decrease in their flow which has followed the increased development. All of the flowing wells lie below the sea-level contour. A few of the northernmost are very near sea level, but the most of them are from 20 to 150 feet below.

COST OF RECLAMATION AND DEVELOPMENT.

The value of lands within the desert depends on their situation relative to the railroad, their fertility, their freedom from alkalies, the improvements which have been made upon them, and the water supply. Those on which successful wells have been bored are, of course, more valuable than those whose water supply has not yet been proved. The unimproved lands have been sold at prices ranging from $10 to $100 an acre. Cultivated land with a proved water supply sells at from $25 to $200 an acre, or even higher in places where the improvements are extensive. Such land occasionally rents for as much as $25 an acre. The majority of the active landowners are residents, have small holdings of 10 to 80 acres, cultivate intensively, and do a great part of their own work. Absentee ownership and large holdings are comparatively rare. A great proportion of the work of clearing new land and preparing it for cultivation is performed by Indians from the reservations along the western side of the valley. They are paid $2.50 an acre for clearing sagebrush and the smaller desert growths and 50 cents each for removing the mesquite trees. The wood obtained from these trees generally pays for the cost of their removal, as it is worth $4.50 per cord at Thermal and Coachella. Some of the lands are covered with hummocks and require grading. The cost of this varies with the amount of work involved, and no accurate estimate can be given.

The drilling of wells by the hydraulic method now in vogue costs about a dollar a foot for both labor and casing for wells of the usual diameters—2 to 4½ inches. Those of larger size are somewhat more expensive. Artesian flows are procured at depths of 275 to 1,000 feet, the shallower waters being found in the southern and western

portions of the basin and the deeper ones in the northern and eastern sections. Wells alone, therefore, range in cost from $200 to as much as $3,000 each—the latter amount being given as the cost of the first successful deep well put down by the Southern Pacific Railroad by the old method, at Mecca.

The average flow is rarely great enough to enable ranchers to irrigate successfully direct from the well. It is customary, therefore, to build small earthen reservoirs (Pl. X, *B*) into which the water flows and from which it is conducted in comparatively large volume for purposes of irrigation. These reservoirs are of simple construction, the walls usually being thrown up by a team and scrapers. Some of them are lined with fine clay; others are unlined. Those that are unlined lose much water by seepage. The reservoirs are not covered, and the loss from them by evaporation during the summer must be considerable. Engineers of the Reclamation Service report that the annual evaporation at Yuma is from 80 to 85 inches, or about 7 feet. It is probably not less from small water surfaces in the vicinity of Indio.

SOILS AND CROPS.

The soils of the Indio area have been carefully studied by J. Garnett Holmes, of the Bureau of Soils, U. S. Department of Agriculture.[a] He divides them into five types, but of these the two most widely distributed and most important agriculturally are sandy loams that differ but slightly in coarseness of grain. Together they cover an area of 135 square miles. This area includes practically all of the valuable lands that are water bearing and yet lie above the extremely alkaline areas, which are extensive in the vicinity of the Salton Sea and along a line that follows approximately the lowest part of the valley from the sink to the vicinity of Indio. Mr. Holmes says of the finer of these loams: "It is well adapted to any crop that is suited to the climate of the area. A better soil for general purposes would be difficult to find, since it is easily cultivated, very productive, and retains moisture well." It is worthy of note that these soils contain a very large percentage of calcium carbonate, ranging from a little less than 2 per cent to nearly 37 per cent in the various samples collected. It is not at all unusual to find soils containing 5, 6, and 7 per cent of this mineral. This high percentage is no doubt due to the very great number of small fossil shells that are scattered over the surface of this portion of the desert and through the soils which underlie it.

The agricultural development of the area is still in its infancy. The ranchers are experimenting on various crops and with various

[a] Holmes, J. Garnett, and party, Soil survey of the Indio area, California; Field operations of the Bureau of Soils, U. S. Dept. Agr., 1903, pp. 1249–1262.

degrees of success. Those most extensively raised at present are melons, barley, and alfalfa. Small tracts, however, have been planted, chiefly for experimental purposes, in grapes, sweet potatoes, oranges, and sugar beets; and at the agricultural experiment station near Mecca rather extensive experiments are being conducted in date culture, a number of the finer, rarer, and more delicate varieties having been introduced from northern Africa and Arabia. Some of the date palms are in bearing, and those in charge of the experiment are sanguine as to its success.

The most highly specialized product of the region is the cantaloupe. The first experiment in its cultivation was made in the summer of 1900. A crate of melons raised during that season was shipped to Chicago, where, because of their high flavor, they found a ready market. Upon the basis of this first venture about 60 acres were planted during the following season, producing 13 carloads and netting to the growers $10,000. The cultivation of this fruit has been successfully continued since, with a constantly increasing acreage. In 1904 the Melon Association of Coachella distributed $67,000 to its members, and in addition the independent operators shipped 11 cars from Indio. The success of the crop is due to the excellent quality of the fruit produced and to the fact that the climatic conditions of the desert permit its early marketing.

Alfalfa and barley are raised with unqualified success, but are less extensively cultivated than melons as a ready money crop. The grapes it is proposed to produce are the fancy table varieties, which the growers expect to place on the market early, as they do the cantaloupes. The vines that have been planted are thrifty, and the experiment promises to be successful. The sweet potatoes that have been produced thus far are excellent in quality; and although they mature early and may be marketed early if there is a demand for them, the growers have found that they are preserved in excellent condition in the dry soil of this climate for months, so that it is not necessary to dig them until market conditions are at their best. Some Indian and Kaffir corn is raised. Sugar beets have been tried as an experiment and have proved successful, but are not extensively cultivated because it is believed that larger returns may be obtained from other crops. Sugar beets have some alkali-resisting qualities and may therefore be raised in lands not suited to the cultivation of more sensitive crops. The date palm is even more capable of resisting alkali. This is especially true after it has become established and deeply rooted. Hence it may prove to be adapted to many soils in the valley where other crops can not be grown.

MAPS AND TABLES.

A map (Pl. XII) has been prepared on which the location of most of the producing wells that had been bored by April, 1907, is shown, the character of each well being indicated by an appropriate symbol. Ordinary domestic wells are represented by a single red dot, artesian wells by a red circle, and pumping plants by a red dot within a circle. Each well is numbered, and the essential facts concerning it—name of owner, location by land lines, diameter, depth, yield, temperature of waters, and cost—are given in the tables that follow. The map shows also approximately the outline of the artesian area, as determined by development, and the areas irrigated.

The data on which this map is based were collected in the field by A. J. Fisk, jr., and W. N. White, who have also rendered great assistance in the office in the preparation of the matter for publication.

Wells in Indio special quadrangle (Map, Pl. XII).

[*Symbols used in tables:* H =hydraulic; B =bored; Dr. =drilled; ? is used after all uncertain data.]

No.	Owner.	Location.			Year completed.	Well.		Depth.	Distance to water.	Temperature of water.	Method of lift.	Quantity of water.	Cost.
		Township.	Range.	Section.		Class.	Diameter.						
		S.	*E.*					*Feet.*	*Feet.*	° *F.*		*Miner's in.*	
1	W. H. Harris	6	8	23	1904	H.	4½ inches	499	.....	74	Artesian	*a* 12	$600
2	....do	6	8	23	1905	H.	...do	509	.....	74	....do	*a* 23	600
3	H. J. Churchman	6	8	23	1904	H.	...do	497	.....	74	....do	*a* 20	600
4	A. L. Gordon & Bro	6	8	23	1904	H.	...do (2)	512	.....	76	Gas, artesian	*a b* 15 *a c* 40	1,000
5	....do	6	8	23	.....	H.	...do	512	.....	76	Artesian	*a* 15	500
6	....do	6	8	23	1904	H.	...do	512	.....	.....	....do	*a* 12	500
7	J. W. Newman	6	8	23	1905	H.	5⅝ inches	526	.....	74	....do	*a* 5	600
8	G. J. Armstrong	6	8	25	1903	H.	4½ inches	538	.....	74	Gas, artesian	.....	*d* 1,100
9	S. B. Twomey	6	8	26	1903	H.	...do	487	.....	74	Artesian	*a* 15	.....
10	J. T. King	6	8	26	1903	H.	...do	514	.....	74	....do	*a* 15	514
11	C. B. Bisbee	6	8	26	1900	H.	3 inches	601	.....	74	....do	*a* 8	.....
12	Mr. Holman	6	8	23	.....	H.	4½ inches	.....	.....	74	....do	.....	.....
13	W. H. Mather	6	8	23	1904	H.	...do	519	.....	74	....do	*a* 15	500
14	Geo. Stepenet	6	8	14	.....	H.	...do	506	.....	74	....do	.....	.....
15	E. D. Morrill	6	8	22	1902	H.	4 inches	498	.....	74	....do	*a* 25	450
16	....do	6	8	22	1904	H.	4½ inches	496	.....	.....	....do	*a* 25	512
17	J. K. Ross	5	7	14	1900	B.	8 inches	86	6	.....	Wind	.....	*d* 136
18	....do	5	7	14	1904	B.	...do	238	8	.....	Not raised	.....	400
19	U. S. Department of Agriculture	7	9	16	1901	H.	4 inches	484	.....	76	Artesian	*a* 20	.....
20	B. G. Johnson	7	9	16	1904	H.	4½ inches	482	.....	.....	....do	*a* 30	500
21	Southern Pacific R. R. Co	5	7	24	1895	Dr.	10 inches	859	.....	.....	....do	½	.....
22	....do	5	7	24	1890	Dr.	...do	660	.....	.....	Steam, artesian	15	.....
23	....do	5	7	24	1900	Dr.	12 inches	665	.....	.....			.....
24	C. B. Smith	7	9	22	1903	H.	4½ inches	510	.....	.....	Artesian	*a* 30	.....
25	R. H. Myers	7	9	22	1903	H.	4 inches	440	.....	.....	....do	1	.....
26	....do	7	9	22	1903	H.	4½ inches	503	.....	.....	....do	*a* 25	.....
27	M. H. Flint	7	9	26	1902	H.	3 inches	530	.....	.....	....do	*a* 14	.....
28	H. J. Rogers	7	9	26	1904	H.	4½ inches	530	.....	.....	....do	.....	.....
29	W. V. Covington	7	9	18	1904	H.	...do	525	.....	76	....do	.....	500
30	....do	7	9	8	1900	H.	2 inches	525	.....	.....	....do	*a* 10	202

a Estimated, or owner's statement used in column "Quantity of water."
b Flows.
c Pumps.
d Cost of well and pumping equipment used in column "Cost of well."

Wells in Indio special quadrangle (Map, Pl. XII)—Continued.

No.	Owner.	Location.			Year completed.	Well.		Depth.	Distance to water.	Temperature of water.	Method of lift.	Quantity of water.	Cost.
		Township.	Range.	Section.		Class.	Diameter.						
		S.	*E.*					*Feet.*	*Feet.*	*°F.*		*Miner's in.*	
31	Walters school district	7	9	8	1903	H.	2 inches	500			Artesian	8	
32	Mecca Land Co	7	9	8	1901?	H.	3 inches	547		77	do	*a* 11	
33	do	7	9	8	1903	H.	4½ inches	531		77	do	13	$530
34	J. R. Robertson	5	7	12	1904	B.	7 inches	186	12		Not raised		200
35	do	5	7	12	1904	B.	do	165	17	74	Hand		200
36	Mrs. V. I. Norsden	5	7	23	1898	H.	2 inches	465		73	Artesian	2	
37	do	5	7	23	1901	H.	4½ inches	500			Gas, artesian	*a* 38	*b* 1,400
38	do	5	7	23	1904	B.	8 inches	218	11		Gas		
39	H. Smith	5	7	23	1899	B.	do	100	20		Wind		*b* 155
40	A. H. Moore	5	7	18	1903	B.	7 inches	165	24		Gas	18	*b* 800
41	N. O. Nelson	5	7	23	1905	H.	3 inches	218	12		Compressed air		
42	do	5	7	23	1903	B.	8 inches	197	14		do		
43	do	5	7	23	1903	B.	do	150	18		do		
44	do	5	7	23	1902	B.	do	370	18		do		
						H.	3 inches	248					
45	do	5	7	23	1903	B.	8 inches	150	18		do		
46	C. A. Hayott	5	7	23	1903	B.	do	155	18		do		
47	P. B. Weir	5	7	13		H.	2 inches	600+		78	Artesian		
48	do	5	7	13		B.	8 inches	480		78	do		
49	Ross estate	5	7	14		H.	2 inches			74	do	4	
50	Will Everett	5	7	14		B.	7 inches	160	12		Wind		
51	do	5	7	14	1903	B.	do	210	9		Gas	5	
52	do	5	7	14	1902	B.	do	150	9		do		
53	D. W. Durbrow	5	7	23	1900	B.	6 inches	652		74	Gas, artesian	*c* 4	
												d 40	
54	do	5	7	23	1894	B.	do	536			Artesian	6	
55	do	5	7	23	1901	H.	4½ in. (2)	600	0		Compressed air		
56	do	5	7	23		B.	6 inches (2)	150	16		do		
57	Fred N. Johnson	5	7	22	1901	B.	7 inches	106	27		Wind		*b* 306
58	do	5	7	22	1903	B.	do	170	27		do		*b* 450
59	do	5	7	22	1904	B.	do	198	22		do		*b* 500
60	Mr. Lewis	5	7	10	1904	B.	7 inches (2)	190	17		Not raised		
61	W. B. Peck Co	5	7	22	1904	B.	8 inches	135	22		Compressed air		
62	do	5	7	22	1904	B.	do	178	22		do		
63	do	5	7	22	1904	B.	do	210	22		do		
64	do	5	7	22	1903	H.	4 inches	534	7		do		
65	do	5	7	22	1897	B.	7 inches	78	22		Wind		

66	....do	5	7	22	1897	B.	...do	61	22		....do			
67	W. S. England	5	7	10	1904	B.	...do	168	16		Not raised			
68	....do	5	7	10	1904	B.	...do	210	15		....do			
69	Berry & Baldwin	6	8	34	1902	H.	4½ inches	510		73	Artesian		37	
70	A. H. Sandford	6	8	34	1904	H.	4 inches	486			....do		12	
71	....do	6	8	34	1902	H.	...do	484			....do		*a* 25	
72	A. D. Nichols	6	8	34	1904	H.	4½ inches	487		73	....do		*a* 34	
73	Toro Indian Reserve	7	8	16	1900?	B.	10 inches	600			....do		(*c*)	
74	....do	7	8	16	1903	H.	4 inches				....do		*a* 25	
75	....do	7	8	16	1903	H.	4 inches (2)	400		81	....do			
76	Moravian Mission	7	8	16	1900	H.	2 inches	300+			....do			
77	W. L. Clabers	7	9	18	1901	H.	3 inches	380		74	....do		*a* 6	
78	D. Bond	7	8	12	1900	H.	...do	408		76	....do		*a* 14	
79	E. Brauckman	7	8	12	1901	H.	3½ inches	480		74	....do		25	
80	....do	7	8	12	1901	H.	4½ inches	480			....do		30	
81	Henry Huskins	6	8	17	.....	H.	4 inches			72	....do		*a* 10	
82	....do	6	8	17	1904	H.	...do			72	....do		*a* 10	
83	Mr. McArthur	6	8	17	.....	H.	4½ inches			73	....do		*a* 10	
84	H. R. Hitchcock	6	8	17	.....	H.	4 inches			73	....do		*a* 6	
85	H. P. Dilworth	6	8	17	1902	H.	4½ inches	558		74	....do		*a* 7	
86	....do	6	8	17	1903	H.	...do	525			....do		18	535
87	Meek Bros	6	8	17	1902	H.	4½ in. (2)	500		72	....do		*a* 30	
88	F. Colby	6	8	20	1900	H.	4 inches	518		73	....do		*a* 10	
89	....do	6	8	20	1903	H.	4½ inches	500		73	....do		*a* 6	500
90	G. B. Evans	6	8	20	1902	H.	...do			74	....do		*a* 16	
91	Mrs. F. Colby	6	8	20	1903	H.	...do	520		74	....do		*a* 16	
92	Mrs. S. A. Williams	6	8	20	.....	H.	4 inches			74	....do		*a* 10	
93	G. B. Evans	6	8	20	.....	H.	...do			74	....do			
94	....do	6	8	20	.....	H.	...do			74	....do			
95	A. O. Hayward	6	8	30	1901	H.	...do	407		74	....do		7	375
96	....do	6	8	30	1902	H.	...do	437		74	....do		8	300
97	G. M. Beach	6	8	30	1904	H.	4½ inches	474		74	....do		23	
98	....do	6	8	30	1904	H.	...do	485			....do		18	
99	H. E. Sheldon	6	8	30	1903	H.	4 inches	430		74	....do			400
100	....do	6	8	30	1901	H.	2 inches	456		74	....do		2	252
101	....do	6	8	30	1902	H.	3 inches	410		74	....do		11	307
102	S. A. Mann	6	7	24	1901	H.	2 inches	320		74	....do			
103	....do	6	7	24	1902	H.	4½ inches	480		74	....do		4	630
104	Albert Sarbaugh	6	7	24	.....	H.	...do				....do			
105	....do	6	7	24	.....	H.	3 inches			74	....do			
106	....do	6	7	24	.....	H.	...do			74	....do			
107	G. M. Frazey	6	7	24	1901	H.	...do	500+		74	....do		4	
108	....do	6	7	24	.....	H.	4 inches	500?		74	....do		5	
109	E. L. Lambie	6	7	14	1901	H.	3 inches	577	4	72	Gas		6	480
110	....do	6	7	14	1901	H.	...do	430	4		....do			
111	....do	6	7	14	1901	H.	...do	418	4		....do			
112	Silas Trickey	7	9	20	1905	H.	4½ inches	480		76	Artesian		37	
113	....do	7	9	20	1903	H.	6½ inches	640		76	....do		33	
114	....do	7	9	20	1904	H.	4½ inches	565		75	....do		30	

a Estimated, or owner's statement used in column "Quantity of water."
b Cost of well and pumping equipment used in column "Cost of well."
c Flows.
d Pumps.
e Small.

Wells in Indio special quadrangle (Map. Pl. XII)—Continued.

No.	Owner.	Location.			Year completed.	Well.		Depth.	Distance to water.	Temperature of water.	Method of lift.	Quantity of water.	Cost.
		Township.	Range.	Section.		Class.	Diameter.						
		S.	*E.*					*Feet.*	*Feet.*	°*F.*		*Miner's in.*	
115	Silas Trickey	7	9	20	1901?	H.	3½ inches	500+		76	Artesian	26	
116	do	7	9	20	1901	H.	4 inches	500+			do	26	
117	E. A. Francis	7	9	8	1903	H.	do	550		76	do	31	$400
118	do	7	9	8	1902	H.	2 inches	563		77	do	3	350
119	L. A. Teagle	7	8	12	1902	H.	4 inches	464		74	do	[a] 35	
120	do	7	8	12	1903	H.	4½ inches	434			do	[a] 60	
121	H. J. Sternberg	7	8	2	1901	H.	3 inches				do		
122	do	7	8	2	1903	H.	4 inches	496		74	do		
123	do	7	8	2	1903	H.	do	495		74	do		
124	do	7	8	2	1905	H.	4½ inches	499		74	do	47	
125	C. D. Miller	7	8	2	1905	H.	do	477		74	do	26	
126	D. F. Baxter	7	8	2	1902	H.	do	550		74	do		
127	F. A. Leap	6	8	35	1901	H.	4 inches	585		74	do	13	565
128	do	6	8	35	1903	H.	do	513			do	23	500
129	R. B. Thayer	6	8	35	1902	H.	do	497		74	do	30	
130	do	6	8	35	1902	H.	do	495		74	do	26	
131	do	6	8	35	1905	H.	4½ inches	504		74	do	[a] 56	
132	do	6	8	35	1904	H.	do	514			do	26	
133	E. N. Stanley	6	8	35	1904	H.	do	515		75	do	33	
134	H. W. Cottle	6	8	35	1901	H.	2½ inches	560			do		
135	do	6	8	35	1905	H.	4½ inches	524			do	[a] 20	525
136	do	6	8	22	1903	H.	3 inches	490			do		
137	Toro Indian Reserve	7	8	26	1902	H.	4½ inches			79	do	[a] 35	
138	do	7	8	26	1902	H.	4 inches			79	do	[a] 25	
139	do	7	8	26	1902	H.	4½ inches				do	[a] 20	
140	Mr. Selig	7	8	34	1902?	H.	4 inches	780		90	do		
141	Southern Pacific R. R. Co	6	8	5	1888	B.	7 inches; inside, 10 inches.	812	4		Not raised		
142	Rector Bros	6	8	5	1904	H.	4½ inches	549		73	Gas, artesian	[b] 15	
143	do	6	8	5	1902	H.	4 inches	638			do	[a b] 9	
144	Town of Coachella	6	8	5	1899?	H.	do	548		73	Artesian	[a] 4	
145	R. D. Smith	6	8	6	1899	H.	2 inches	557		73	Hand, artesian	2	
146	do	6	8	6	1902	H.	4 inches	540			Gas, artesian	[b] 7 [c] 45	[d] 2,550
147	do	6	8	6	1902	H.	do	542			do		

148	....do	6	8	6	1902	H.	...do	557				....do	[b] 4	
149	Seth J. Hardison	6	8	7		H.	3⅝ in. (2)	500 ?				Artesian	7	
150	Ed Goth	6	8	6	1901	H.	4½ in. (2)	535					[a] 50	[d] 2,000
150a	....do	6	8	6	1901	H.	3 inches	131	13			Gas, artesian		
151	Geo. C. Huntington	6	8	6	1903	H.	4 inches	586			70	Artesian, gas	[a] 18	
152	A. Golch	6	8	6	1904	H.	4 inches (2)	500+						
						B.	8 inches (2)	115	9			Artesian, gas	[b] 8	
													[c] 40	
153	....do	6	8	6	1902	H.	4½ inches	500				....do		
					1905	B.	8 inches	140				Gas	20	
154	....do	6	8	6		B.	10 inches	590				Artesian, gas	[b] 1	
						B.	8 inches	115	11			Gas		
						B.	10 inches	150	11			....do		
155	F. R. Strong	6	8	6	1902	H.	2 inches (2)	540 ?				Compr. air, artesian	[b] 10	[d] 3,800
						H.	4 inches (3)						[c] 140	
156	....do	6	8	6	1904	B.	8 inches (4)	135	20			Gas	30	[d] 1,800
157	Coachella Land and Water Co	5	8	25	1902	B.		550				Artesian		
						B.		250	30			Not raised		
158	C. C. Robertson	5	8	31	1901	H.	2 inches	600				Artesian	3	
159	....do	5	8	31	1902	H.	4 inches	550				Artesian, gas		
					1904	B.	6 inches	197	16			Gas	[a] 40	[d] 2,000
					1904	B.	8 inches	85	16			....do		
160	Mr. Teagle	5	8	31		H.	4½ inches	627				Artesian, gas		
						B.	...do	298	22			Gas	59	[d] 2,200
						B.	5⅝ inches	216	22			....do		
161	M. J. Murray	5	8	31		H.	8 inches (2)	545				Gas, artesian	40	[d] 1,750
							4½ inches							
					1901	H.	4 inches	580		722		....do		
162	F. E. Halloway	5	8	31	1904	H.	4½ inches	540		727		....do	[a] 28	[d] 2,300
					1904	B.	7⅝ inches	116	16	727		Gas		
163	Rector Bros	6	8	5	1901	H.	3½ inches	556		732		Artesian	[f]	
164	Coachella Bank	6	8	5		H.	...do	550		73		....do		
165	Coachella Land and Water Co	6	8	5		H.	4½ inches	553		73		....do		
166	....do	6	8	5		H.	...do	540		73		....do	16	500
167	....do	6	8	5		H.	4 inches	548		73		....do		
168	Ruddock & Trench	6	8	5	1900	H.	4½ inches	558		73		Artesian, gas	[a] 30	1,150
					1901	H.	...do	547		73		....do		
169	Rector Bros	6	8	8		H.	...do	545		73		Artesian	[a] 40	
						H.	...do. (2)	563		73		....do		
170	H. Woods	6	8	8		H.	4 inches (2)	500?		73		....do	5	
171	A. W. Haight	6	8	8		H.	3 inches			73		....do	5	
172	Coachella Valley Refrigerating Co	6	8	5	1905	H.	4½ inches			73		....do		
173	C. E. Mawby	6	8	5	1902	H.	4 inches	541		73		....do	4	
174	....do	6	8	5		H.	4½ inches	500?	15			Not raised		
175	C. Banta	6	8	8	1904	H.	...do	528				Artesian, gas	[a] 40	
						B.	5⅝ inches	160	12			Gas		
176	I. H. Fay	6	8	8	1902	H.	4⅝ inches (2)	510		73		Artesian, gas	20	[d] 1,650
177	C. O. Carlson	6	8	8	1902	H.	4 inches (2)	510		73		Artesian	19	1,000
178	....do	6	8	8		H.	4 inches	542				....do	9	

[a] Estimated, or owner's statement used in column "Quantity of water."
[b] Flows.
[c] 3 pumps.
[d] Cost of well and pumping equipment used in column "Cost of well."
[e] Pumps.
[f] Small.

Wells in Indio special quadrangle (Map, Pl. XII)—Continued.

No.	Owner.	Location.			Year completed.	Well.		Depth.	Distance to water.	Temperature of water.	Method of lift.	Quantity of water.	Cost.
		Township.	Range.	Section.		Class.	Diameter.						
		S.	*E.*					*Feet.*	*Feet.*	°*F.*		*Miner's in.*	
179	C. O. Carlson	6	8	8	.....	H.	4 inches	527	.....	.....	Artesian	12	.....
180	Hummel Bros	6	8	8	1904	H.	(2 wells)	500?	.....	.....	do	[a] 15	.....
181	G. M. Beach	6	8	8	1903	H.	4½ inches	500	.....	.....	do	23	.....
					1905	H.	do	495	.....	.....	do	26	.....
182	W. I. Hobbs	6	8	8	1904	H.	4 inches	500	.....	.....	do	21	$300
183	do	6	8	8	1902	H.	4½ inches	500	.....	.....	do	[a] 8	.....
184	Seth Hardison	6	8	7	.....	H.	4½ inches (2)	.....	.....	.....	do	.....	.....
185	do	6	8	7	.....	H.	4½ inches	.....	.....	.....	do	.....	.....
186	Frank R. Strong	6	8	7	.....	H.	4⅝ inches	.....	.....	.....	do	16	.....
187	A. J. Hoskin & Son	6	8	7	1904	H.	4½ inches	508	.....	.....	Artesian, gas	[a] 40	[b] 1,712
						B.	5⅝ inches	120	8	.....	Gas		
188	N. C. Hanson	6	8	8	1903	H.	4 inches (2)	522	.....	.....	Artesian	[a] 12	1,500
					1900	H.	2 inches	540	.....	.....	do		
189	Mrs. N. C. Hanson	6	8	8	1904	H.	4½ inches	522	.....	.....	do	.....	525
190	J. P. Baker	6	8	8	1904	H.	do	550	.....	.....	do	12	550
191	Mr. White	6	8	9	1904	H.	do	540	.....	.....	do	[a] 27	540
192	Coachella Land and Water Co	6	8	9	1902	H.	.....	543	.....	.....	do	.....	.....
						B.	8 inches	.....	.....	.....	do	.....	.....
193	Dillman & Baldwin	6	8	7	.....	H.	2⅝ inches	.....	.....	.....	Artesian and gas	.....	.....
						B.	7 inches	.....	.....	.....	Gas	.....	.....
194	do	6	8	7	.....	H.	4½ inches	535	.....	.....	Artesian	5	535
195	Hugh Montgomery	6	8	7	.....	H.	3½ inches	540	.....	.....	do	[a] 3	600
196	S. C. Grindley	6	8	7	1902	H.	(3 wells)	500	.....	.....	do	25	.....
						B.	.....	200	.....	.....	Gas	.....	.....
197	W. J. McMillan	6	7	12	1900	B.	7 inches	200	18	72	do	.....	.....
					1904	H.	3 inches	500	.....	72	Artesian, gas	.....	.....
198	C. R. Cawthon	6	7	12	.....	B.	5⅝ inches	86	.....	.....	Artesian	.....	.....
						B.	8 inches	110	.....	.....	do	.....	.....
						H.	3½ inches	500?	.....	.....	do	4	.....
						H.	4 inches	500?	.....	.....	do	4	.....
199	do	6	7	12	1902	H.	do	500	.....	72	Artesian, gas	[a] 25	.....
					1904	B.	4½ inches	177	20	.....	Gas		
200	Mr. Bauer	6	7	12	.....	H.	4 inches	.....	.....	72	Artesian	9	.....
201	J. Holliday	6	7	12	.....	H.	do	500	.....	.....	Artesian, gas	[c] 2	.....
202	Mr. Bauer	6	7	22	.....	B.	.....	.....	30	.....	Gas	.....	.....
203	E. Holley	6	7	16	1905	B.	8 inches	177	42	.....	do	[a] 40	[b] 1,426

204	Mrs. Kearny	6	7	16	1905	B.	...do	215	43		Not raised		
205	E. Holley	6	7	8	1903	B.	7 inches	124	40		....do		
206	Taitt & Hall	6	7	16	1904	B.	8 inches	123	48		Gas		
207	Marshall & Green	6	7	6	1902	B.	7 inches (2)	100	45		....do	[a]60	
208	A. P. Green	6	7	6		B.	7 inches	190	45		Not raised		
210	J. R. Thurmond	6	7	34	1903	H.	4 inches		74		Artesian	(d)	
211	Mr. Bauer	6	7	26	1903	H.	3 inches	300?	74		....do	(d)	
212	Mrs. O'Flanagan	6	7	26		H.	4 inches				....do	(d)	
213	Mr. Cohagen					H.	...do				....do	1	
215	J. R. Thurmond	6	7	26	1901 1903	H. H.	...do 3 inches	329 320	74 74		....do ....do	13 10	
216	J. B. Alvord	6	7	35		B.	10 inches		74		....do	8	
217	....do	6	7	35		H.	4 inches				....do	7	
218	....do	6	7	35		B.	8 inches		74		....do	(d)	
219	J. S. Glenn	6	7	25	1903	H.	4½ inches	385	74		....do	[a]9	
220	....do	6	7	25	1903	H.	...do	337			....do	3	
221	O. C. Eberhardt	6	7	36	1901	H.	4 inches	340	74		....do	4	
222	....do	6	7	36	1900	H.	2½ inches	340	74		....do	7	
223	....do	6	7	36	1901	H.	3½ inches	340	74		....do	11	
224	....do	6	7	36	1901	H.	4 inches	340	74		....do	14	
225	A. T. Mann	6	7	36	1905	H	4½ inches	327	74		....do		327
226	J. Ainsley	6	7	36	1901	H.	3 inches	340	74		....do	6	
227	G. L. Bugbee	7	7	1	1905	H.	4½ inches	370	74		....do	26	375
228	Dozier Lewis	7	8	6	1902	H.	4 inches (2)	340	74		....do	[a]30	
229	G. L. Bugbee	7	7	1	1902	H.	5⅝ in. (2)	385	74		....do	15	
230	J. A. Barton	7	7	1	1904 1903	H. H.	4½ inches 4 inches	372 282			....do ....do	17	625
231	Toro Indian Reserve	7	7	2		H.	4½ in. (2)		75		....do		
232	....do	7	7	2		H.	...do		74		....do		
233	....do	7	7	2		H.	...do		75		....do		
234	....do	7	7	2		H.	4½ inches		76		....do		
235	Seth Hardison	6	8	18		H.	4½ in. (2)		73		....do	[a]14	
237	Fred O. Todd	6	8	32	1901 1902	H. H.	4½ inches 3¾ inches	397 400	73 73		....do ....do	15 21	
238	....do	6	8	32	1903 1904	H. H.	4½ inches 4½ inches	540 484	74 74		....do ....do	17 32	
239	W. A. Snyder	6	8	32	1903	H.	4 inches	456			....do		
240	F. H. Hunt	6	8	32	1901	H.	3½ inches	336			....do	[a]1	
241	W. R. Prouty	6	8	32	1903	H.	4½ inches	448	74		....do	[a]23	
242	....do	6	8	32	1901	H.	4 inches	438	74		....do	[a]6	
243	Mr. Vogt	6	8	32		H.	...do		74		....do	15	
244	Stanley & Payne	7	8	4		H.	4½ inches	474	74		....do	[a]7	
245	Glenn Bros	7	8	4		H.	3½ inches		74		....do		
246	....do	7	8	4		H.	6 inches		73		....do	[a]8	
247	Mrs. T. F. Thompson	7	8	4	1904	H.	4½ inches	440	74		....do	[a]23	
248	Thermal School District	6	8	22	1903	H.	4½ inches	498	74		....do	[a]8	
249	A. P. Green	6	8	22	1900	H.	4 inches	375	74		....do	14	
250	Thermal Land Co	6	8	22	1902	H.	5⅝ inches	520	74		....do	[a]25	
251	....do	6	8	22	1902	H.	...do	520	74		....do	[a]10	

[a] Estimated, or owner's statement used in column "Quantity of water."
[b] Cost of well and pumping equipment used in column "Cost of well."
[c] Flows.
[d] Small.

Wells in Indio special quadrangle (Map, Pl. XII)—Continued.

No.	Owner.	Location.			Year completed.	Well.		Depth.	Distance to water.	Temperature of water.	Method of lift.	Quantity of water.	Cost.
		Township.	Range.	Section.		Class.	Diameter.						
		S.	*E.*					*Feet.*	*Feet.*	*°F.*		*Miner's in.*	
252	Mr. Martin	6	8	22	.....	H.	4½ inches	520	.....	74	Artesian	21	.....
253	J. L. F. McLain	6	8	26	1901	H.	4 inches	572	.....	74	....do	*a* 16	.....
254	....do	6	8	26	1904	H.	4½ inches	510	.....	74	....do	*a* 19	$570
255	Martin & Moore	6	8	26	1902	H.	3½ inches	500	.....	74	....do	11	.....
256	....do	6	8	26	1900	H.	4 inches	511	.....	74	....do	9	.....
257	....do	6	8	26	1900	H.	...do	517	.....	.....	....do	*a* 16	.....
258	Magaw Bros	6	8	35	1904	H.	4½ inches	509	.....	74	....do	26	.....
259	J. A. Potter	6	8	35	1904	H.	4 inches	500	.....	74	....do	19	.....
260	Mr. Hutchings	6	8	35	1904	H.	4½ inches	.....	.....	74	....do	38	.....
261	G. L. Keith	6	8	22	1905	H.	4 inches	577	.....	74	....do	20	.....
262	Toro Indian Reserve	5	8	32	.....	Dug.	4 by 4 feet	18	16	.....	Hand	.....	.....
263	....do	5	8	32	.....	H.	4½ inches	500	.....	.....	Artesian	.....	.....
264	Rector Bros	6	8	4	1901	H.	...do	542	.....	75	....do	12	.....
265	Mr. West	6	8	4	.....	H.	5½ inches	500?	.....	75	....do	*a* 4	.....
266	....do	6	8	4	.....	H.	4 inches	500?	.....	75	....do	8	.....
267	Ruddock & Trench	6	8	4	.....	H.	...do	500?	.....	75	....do	.....	.....
268	Rector Bros	6	8	4	1902	H.	...do	500?	.....	74	....do	16	.....
269	....do	6	8	5	1904	H.	...do	574	.....	74	....do	12	.....
270	Thermal Land Co	6	8	10	1903	H.	4½ inches	526	.....	75	....do	*a* 8	.....
271	....do	6	8	10	.....	H.	...do	532	.....	75	....do	*a* 10	.....
272	....do	6	8	10	.....	H.	...do	517	.....	75	....do	*a* 8	.....
273	B. F. Boome	7	8	34	1902	H.	4 inches	200	0	.....	Not raised	.....	.....
274	....do	7	8	34	1901	B.	8 inches	220	30	91	Gas	35	*b* 1,500
275	....do	7	8	34	1901	H.	4 inches	250	25	91	....do		
276	Mr. Yhost	8	8	14	.....	H.	3 inches	300	.....	92	Artesian	3	.....
277	Peters, Evans & Gage	8	8	24	1902	B.	10 inches	315	.....	94	....do	35	.....
278	....do	8	8	24	1902	B.	...do	315	.....	90	....do	66	.....
279	....do	8	8	24	.....	H.	4 inches	.....	.....	88	....do	8	.....
280	F. S. Everett	5	7	14	1899	B.	7 inches	170	16	.....	Wind	.....	*b* 350
281	....do	5	7	14	1903	B.	7 inches (2)	175	16	.....	Gas	25	1,150
282	Southern Pacific R. R. Co	8	9	2	.....	H.	2 inches	502	.....	.....	Artesian	.....	.....
283	....do	8	9	2	.....	H.	...do	708	.....	.....	....do	.....	.....
284	....do	8	9	2	.....	H.	...do	555	.....	.....	....do	.....	.....
285	....do	8	9	2	.....	H.	...do	589	.....	.....	....do	.....	.....
286	....do	7	9	17	.....	Dr.	(2 wells)	480	.....	.....	....do	.....	.....
287	Peters, Evans & Gage	8	8	24	1902	B.	10 inches	601	5	.....	Not raised	.....	.....

288	Mr. Yhost	8	8	14	1905	H.	8 inches				Artesian	12		
289	J. P. Kiler	7	9	8	1906	H.	4½ inches	582			Gas, artesian			3,000
290	C. R. Harris	7	8	12	1906	H.	...do	432			Artesian	16		432
291	....do	7	8	12	1903?	H.	4 inches	464		70	....do			510
292	C. L. Edmunds	7	8	2	1906	H.	4½ inches	413			....do	22		375
293	....do	7	8	2	1906	H.	...do	417			....do	24		375
294	D. K. Baxter	7	8	2	1906	H.	...do				....do	33		
295	J. P. Read	7	8	2	1905?	H.	...do	497			....do	[a]25		
296	J. S. Leach	6	8	35	1906	H.	...do	517			....do	13		
297	A. W. McGill	6	8	26		H.	...do	530			....do	15		540
298	Martin & Moore	6	8	26		H.	...do				....do	3		
299	J. H. Bell	6	8	26	1905	H.	...do	503			....do	[a]10		500
300	....do	6	8	26	1906	H.	...do	513?			....do	[a]10		515
301	C. B. Bisbee	6	8	26	1906	H.	...do	590			....do	5		
302	Butler Bros	6	8	23		H.	...do	499			....do	3		
303	Mrs. Brook	6	8	23	1905	H.	...do	495			Gas, artesian	[a c]5 [a d]20		1,700
304	Adams & Butman	6	8	22	1907	H.	...do	575			Artesian	18		
305	....do	6	8	22	1900?	H.	...do 3½ inches	497			....do	[a]15		
306	Oakley Wood	6	8	34	1307	H.	4½ inches	436			....do	[a]40		
307	Payne Bros	6	8	17	1905	H.	...do	522			....do	3		
308	Holland Bros	6	8	33	1907	H.	...do	493			....do	34		
309	....do	6	8	33	1907	H.	...do	496			....do	[a]20		
310	J. H. Thurston	5	8	31	1905	B.	6 inches (2)	240	15		Gas	[a]55–60		
311	D. C. Huntington	5	8	31	1905	B.	6 inches	160	9		....do	[a]30		
312	S. Starett	6	8	6	1906	H.	4 inches	1,052			Artesian	9		
313	C. W. Hyde	5	8	31	1906	B.	8 inches	221	16		Gas	30		1,025
314	W. A. Caldwell C. B. Estle Geo. Gillons	5	7	25	1903	B.	...do	100	22		....do	65		
315	Mr. Baeyertz							150						
316	J. A. Semple	5	7	24	1907	H.	4½ inches	156	20		Gas			435
317	G. W. Durirew	5	7	23	1906	H.	5¾ inches 3 inches	1,000+			Artesian	2		
318	C. E. Cooper	5	7	14	1900?	B.?	6 inches(?)	80	15½		Not used			
319	Fred N. Johnson	5	7	22	1907	B.	7¾ inches	119	16?		Wind			

[a] Estimated, or owner's statement used in column "Quantity of water."
[b] Cost of well and pumping equipment used in column "Cost of well."
[c] Flows.
[d] Pumps.

INDEX.

A.

	Page.
Alamo River, creation of	9
Alkali, deposition of	37
prevalence of	9, 13
Arroyo, dry, view of	22
Artesian areas, map showing	Pocket.
Artesian waters, development of	6–7, 10
extent of	34
prevalence of	27
salt in	27–28

B.

Barret well, boring of	26
Basins, flood, occurrence of	30–31
Bed rock, depth to	15
Black Mountains, rocks of	11
Blake, W. P., on Colorado Desert	6–7, 20

C.

Cahuilla, Lake, history of	18–20
Calcium carbonate, deposition of	18
incrustation of, view of	14
California Development Co., operations of	21
Cantaloupes, cultivation of	43
Carrizo Mountains, rocks of	11, 16
Coachella, well at	7
Coachella Valley, section through, figure showing	12
See also Indio region.	
Colorado River, delta of	17–18
grade of	20–21
inflow of, to Imperial Valley	22–24
Colton, rocks near	10
Cottonwoods, view of	36
Crops, character of	42–43
Cultivation, acreage of	40–41

D.

Delta silts, description of	25
Desert homestead, view of	36
Deserts, dangers of	5
Dioritic rocks, occurrence of	10
water in	10
Drainage, description of	28, 30–31

E.

Evaporation, amount of	18, 42
importance of	37, 39
Exploration, history of	6–7

F.

Faulting, occurrence of	14, 15
Figtree John's, rocks at	10
wells near	31
Fish Springs, view at	20
Flood basins, occurrence of	31
Fossils, evidence of	19
scarcity of	13

G.

Geography, description of	7–10
Geology, description of	10–28
Granitic rocks, occurrence of	10
water in	10
Gulf of California, extent of	17

H.

Hanna well, boring of	26
Harper well, boring of	26
History of region	5–7
Holmes, I. G., on soils of region	42

I.

Imperial, rocks near	13, 16
Imperial canal system, history of	21–24
Imperial Junction, mud volcanoes at	14
mud volcanoes at, view of	32
rocks near	13, 16
Imperial Valley, flooding of	22–24
irrigation in	7, 21–24
location and character of	
settlement in	21–22
Indians, testimony of, on Salton Sea	19–20
Indian Well, rocks at	10
Indio, Cal., rainfall at	29
rocks near	12
wells near	31–32, 40
section of, figure showing	33
yield of	35
Indio region, development of	40–41
location of	9–10
wells of	31
waters of	31–32
analyses of	32
Irrigated lands, map showing	Pocket.
Irrigation, development of	7

L.

Land, value of	41
Lano station, wells near	31
Lowland, origin of	14–17

M.

McCain Springs, discovery of	6
Map of Indio region, showing wells, etc.	Pocket.
of Salton Sink	Pocket.
Mecca, rocks near	12–14
section through, figure showing	12

Page.

Mecca, well at 7
section of, figure showing 33
Mortmere, wells near 31
wells near, section at, figure showing 33

N.

New Liverpool Salt Co., well of 27, 31
work of 27
New River, creation of 9
flood in 22

O.

Obsidian cones, occurrence of 14
Oil, borings for 11, 25–26

P.

Palm Canyon, water of 30
Palm Springs, Cal., rainfall at 29
Peninsula Range, description of 8
rocks of 10
Pumping, advantages of 38

R.

Railroad lands, sale of 40
Railways, construction of 7
Rainfall, records of 28–31
Reclamation, cost of 41–42
Red Canyon, view in 10
Reservoirs, construction of 42
view of 36
Rivers, creation of 9
Roads, course of 5–6

S.

Salada, Laguna, location of 8
Salines, occurrence of 27–28
Salt, production of 9, 27
Salton Sea, effects of 37–39
history of 18–20
rocks in 13
view of 40
water line of 14, 18, 20
well in 27, 31
Salton Sink, map of ..... Pocket
San Bernardino Mountains, description of 8
Sand blast, effects of 26–27
views of 26
Sand dunes, occurrence of 9, 10, 26–27
view of 28
Sandstones, occurrence of 16
San Gorgonio Mountains, rocks of 11–12
San Jacinto Mountains, location of 8
rocks of 10
Santa Rosa ridge, location of 8

Page.

Santa Rosa ridge, rocks of 10, 16
San Timoteo Canyon, wells in 10
Settlement, progress of 7
Shales, occurrence of 10
water in 10–11
Signal Mountains, rocks near 16
Silts, description of 25
Soils, character of 42
Solfataras, description of 14
Springs, occurrence of 11
Structure, description of 10–14
Subsidence, evidence of 14–17
Superstition Mountain, rocks of 13

T.

Tahquitz Creek, description of 30
Tertiary deposits, canyon in, view of 14
description of 25–26
Thermal, well at 7
Tragedies, continuance of 5

V.

Valley deposits, description of 24–28
Vegetation, occurrence of 8–9
Volcanoes, mud, occurrence and description of. 14
view of 32

W.

Walters, well at 40
Water, alkali in 13
Water, artesian. *See* Artesian water.
Water, underground, conservation of 36–37
course of, figure showing 38
development of 6–7, 10, 25–26
draft on 35–36
future of 37–38
quality of 27–28, 34
source of 30, 34–35
limits of 31–34
supply of 34–35
waste of 36–37
Water resources, description of 28–40
Wells, cost of 41–42
location of, map showing ..... Pocket
table of 45–53
Wells, yield of 35–36
See also Waters, underground.
Whitewater River, description of 30
Williamson, R. S., exploration by 6

Y.

Yucaipe Valley, wells in 10
Yuha well, boring of 26
Yuma, Ariz., rainfall at 29

O

U S GEOLOGICAL SURVEY
GEORGE OTIS SMITH DIRECTOR

WATER SUPPLY PAPER NO 225 PL I

RECONNAISSANCE MAP OF THE

SALTON SINK, CALIFORNIA

E M Douglas Geographer — R B Marshall in charge of Section
W C Mendenhall Geographer

Adjoining areas in the topographic maps of the Geological Survey are outlined. Places mentioned in the text are

U S GEOLOGICAL SURVEY
GEORGE OTIS SMITH DIRECTOR

WATER SUPPLY PAPER NO. [illegible]

MAP OF THE INDIO REGION, CALIFORNIA

SHOWING WELLS, ARTESIAN AREA AND IRRIGATED LAND

BY W. N. WHITE AND [illegible]

UNDER THE DIRECTION OF W. [illegible] MENDENHALL

Scale [illegible]

LEGEND

Domestic well

Artesian well

Pumping plant

Irrigated land

Indio
Myoma
Toro
Mecca
Martinez
Alamo Bonito
Mortimer
Agua Dulce
El Mesa
The Point
Devil Canyon
Toro Canyon
Agua Alta Canyon
Casa de Cuerva
Martinez Canyon
Rabbit Peak
Barton Canyon
Clark Well
Clark Lake
Coyote Mts.
SANTA ROSA MOUNTAINS
SALTON BASIN
WATER SURFACE 188 FT. BELOW SEA LEVEL
ABANDONED
PACIFIC
SOUTHERN
I R
RIVERSIDE CO
SAN DIEGO CO
IMPERIAL CO
T 6 S
T 7 S
T 8 S
T 9 S
R 7 E
R 8 E
R 9 E

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

WATER-SUPPLY PAPER 226

THE POLLUTION OF STREAMS BY SULPHITE PULP WASTE

A STUDY OF POSSIBLE REMEDIES

BY
EARLE BERNARD PHELPS

Investigation made at the Sanitary Research Laboratory and Sewage Experiment Station of the Massachusetts Institute of Technology

WASHINGTON
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CONTENTS.

	Page.
Introduction	5
Stream pollution by sulphite pulp waste liquor	6
General discussion	6
Pollution of Lake Champlain	6
Pollution of James River	6
Pollution of Potomac River	8
Pollution of Black River	8
Manufacture of sulphite pulp	8
The wood	9
The acid liquor	9
The digester	10
The "cook"	11
Screening and washing the stock	12
Bleaching the stock	13
Summary	15
Sulphite pulp waste liquor	15
Previous investigations	15
Amount of waste per ton of pulp	18
Chemical composition of the waste liquor	20
Chemical nature of the organic material	21
Purification of sulphite waste liquor	22
Utilization of sulphite waste liquor	24
Experimental investigations with the organic material	27
Preparation of crude "lignone"	28
Solubility of crude "lignone"	28
Reactions with phosphorus chlorides	28
Fusion with alkali	29
Position of the sulphur in "lignone"	29
Reactions with aromatic amines	30
Reactions of the amine-condensation products with nitrous acid	31
Reactions with nitric acid	31
Lignone yellow	32
Reactions of the amine-condensation products with nitric acid	33
Sulphur dyes	34
Commercial possibilities of lignone dyes	35
Conclusion	35
Survey publications on stream pollution	37

ILLUSTRATION.

	Page.
PLATE I. Diagram illustrating the steps in the manufacture of wood pulp by the sulphite process	16

THE POLLUTION OF STREAMS BY SULPHITE PULP WASTE—A STUDY OF POSSIBLE REMEDIES.[a]

By Earle Bernard Phelps.

INTRODUCTION.

The pollution of streams by the waste liquors resulting from the manufacture of paper pulp by the sulphite process constitutes one of the most serious stream-pollution problems with which science has to deal at the present time. The seriousness of the problem is the direct result of two factors the tremendous volume of such waste liquors and their high content of organic matter of extremely undesirable character. An approximate estimate of the amount of sulphite waste liquor discharged into the streams of the United States in one year is given in the subjoined statement, compiled from data in Forest Circular No. 120, Forest Service, United States Department of Agriculture.

Amount of sulphite waste liquor discharged into streams of the United States during 1906.

	Million gallons.
Maine	560
Massachusetts	45
Michigan	175
New Hampshire	380
New York	1,000
Ohio	41
Oregon	52
Pennsylvania	217
Virginia	84
West Virginia	89
Wisconsin	540
All other States	44
	3,227

According to the above estimate, the total amount of this liquor discharged into streams throughout the country in one year is more than three billion gallons, and when it is considered that of this enormous amount 10 per cent by weight, or more than 2.5 billion pounds, is solid matter, mostly organic, it will be readily conceded that the problem of its disposal is one of no small magnitude.

[a] This investigation was made in cooperation with the sanitary research laboratory and sewage experiment station of the Massachusetts Institute of Technology.

STREAM POLLUTION BY SULPHITE PULP WASTE LIQUOR.

GENERAL DISCUSSION.

Though the pollution of streams by sulphite pulp waste is an obvious and serious matter in the region where sulphite mills exist, the literature contains but few references which throw any light on the actual damage caused. In Germany the regulations of the sanitary authorities are strict. Ahrens [a] states that pulp manufacturers, in spite of constant endeavor, may come into conflict with the authorities because they are not able to meet the requirements in regard to the discharge of waste waters into rivers, and he adds that many factories in Germany have actually been obliged to shut down for that reason. Sanitary officers in the United States are more lenient. This is due partly to the fact that the streams in this country are larger and the greater number of the sulphite mills are located in less densely populated regions.

POLLUTION OF LAKE CHAMPLAIN.

In some places stream pollution from this cause has been so serious as to warrant investigation. Leighton,[b] in his investigation of the pollution of Lake Champlain, made a study of sulphite pulp waste as it affects Ausable River, which he found to be a black, foul, grossly polluted stream in which the existence of fish or other forms of life is impossible. He concluded, however, that the great dilution of the river waters by those of the lake renders the pollution insignificant so far as the lake waters are concerned.

POLLUTION OF JAMES RIVER.

Levy[c] made a careful study of the effect of sulphite waste pollution on James River. The sources of pollution are at Covington, Va., about 250 miles by water above Richmond, whose public supply is derived from this stream. Levy found Jackson River, into which this liquor is discharged and which unites with the Cowpasture below Iron Gate to form the James, to be perfectly clear and colorless. The waste entering the stream first turns the water dark brown and later a purplish black. Foam is created at the outfall and wherever the stream is interrupted by falls or by rapids. This appearance can be noted for the entire distance from Covington to Richmond. Dilution is practically the only means of improvement. On the sanitary side of the question Levy considers two problems—(1) whether

[a] Zeitschr. angew. Chemie, 1895, p. 41.

[b] Leighton, M. O., Preliminary report on the pollution of Lake Champlain: Water-Supply Paper U. S. Geol. Survey No. 121, 1905.

[c] Levy, E. C., Report to the water committee on the investigation of the effect of trades wastes on the water of James River at Richmond. Richmond, 1905.

the substances introduced are themselves actually injurious to health, and (2) what influences they may have on the multiplication of bacteria. The liquor itself as it enters the river is absolutely sterile, not only on account of the actual germicidal substances which it contains, but also on account of the fact that it has been subjected for about twelve hours to steam under a pressure of 80 pounds to the square inch. Its germicidal properties are shown in the following table:

Germicidal action of sulphite waste liquor on bacteria in highly polluted water from Shockoe Creek.

[By E. C. Levy.]

Per cent, by volume, of liquor in mixture.	Number of bacteria per cubic centimeter.			Per cent of reduction (−) or increase (+).	
	At start.	After 6 hours.	After 24 hours.	In 6 hours.	In 24 hours.
0 (control)	450,000	900,000	2,500,000	+100	+ 455
1	445,000	.....	[a] 7,500,000	.....	+1,585
5	427,500	60,000	170,000	− 86	− 60.2
10	405,000	35,000	0	− 91.4	− 100
25	337,500	10	0	−100	− 100

[a] Plate liquefied.

The number of bacteria in the water at the commencement of the experiment is calculated from the number of bacteria present in the creek water itself (450,000). Where the reduction is more than 99.95 per cent it is given as 100 per cent. Even very small amounts of the waste liquor have an antiseptic action, but are not actually germicidal; they restrain the growth of bacteria without killing them. Such action may be harmful rather than otherwise, for in a stream receiving sewage certain kinds of bacteria eventually render the sewage harmless. It would seem that as the character of this waste is so stable it does not furnish food for bacterial growth.

Complaint is made that the water of the James at Richmond is unfit for boiler use, both on account of its corrosive action and on account of the "priming" due to vegetable matter present. Aside from the matter of actual harm, however, Levy states that the water is rendered objectionable in appearance by this waste. The dark-brown, almost black water, with its accumulation of dirty scum, is not relished by the consumer, even if he knows that it is probably safe to drink it. In a bath tub this color is very pronounced, and even in so small a quantity as a tumblerful it is decidedly noticeable. James River is practically clear for certain periods of each year, and at such periods, under normal conditions, no further treatment than mere storage would be required for furnishing satisfactory water. But during these periods, on account of the low stage of the

river, the trouble from Covington is most marked. Plain sedimentation has absolutely no effect on the color; but coagulation will remove a large part of it, and Levy found not less than 3 grains of alum per gallon necessary for this purpose. He estimates that with a daily consumption of 14,000,000 gallons it would cost $75 a day for alum, which would not be required if it were not for the sulphite pollution, and states that even then the water would not be perfectly satisfactory.

Farther up the river complaints have been made that fish have been killed by the sulphite waste. The opinion is expressed that if fish are killed it is perhaps because the free oxygen, which is necessary for their life, is used up, rather than because of the presence of substances actually poisonous in themselves.

POLLUTION OF POTOMAC RIVER.

Some experiments to determine the effect of sulphite waste pollution on fish life in Potomac River are reported by Marsh.[a] He found a decidedly injurious effect on fish of different kinds in dilutions varying in strength from 1 part of waste liquor in 50 parts of water to 1 part in 200 parts of water.

POLLUTION OF BLACK RIVER.

Whipple[b] has referred to the effect of sulphite pollution on the water supply of Watertown. He states that the sulphite liquors contribute to the odor and color of the water, and necessitate the use of greater amounts of alum than would otherwise be necessary.

MANUFACTURE OF SULPHITE PULP.

In order that the character and amount of the waste liquors resulting from the manufacture of wood pulp by the sulphite process may be comprehended it will be necessary to describe, in some detail, the various operations that are conducted in a sulphite mill to convert spruce logs into paper pulp. The processes in use at the Mechanicsville mill of the West Virginia Pulp and Paper Company will be described, as they are typical of a modern sulphite mill of average capacity. Though there are naturally many variations in minor details, the essential steps are similar at all mills, so that a detailed description of the processes of one mill, with an occasional statement of important alternative methods, will serve the purpose of this discussion.

[a] Marsh, M. C., in Parker, H. N., and others, The Potomac River basin: Water-Supply Paper U. S. Geol. Survey No. 192, 1907.

[b] Whipple, G. C., Proc. Watertown Soc. Eng., Watertown, N. Y., 1906.

THE WOOD.

Spruce and hemlock are the woods used almost exclusively for the manufacture of pulp by the sulphite process. The logs are either barked by hand in the woods before seasoning or by machinery at the mill. Machine barking necessitates cutting the log into 2-foot lengths; in hand work 4-foot lengths are used without further cutting. Machine barking also causes some waste of material through cutting too deeply into the log. Some measurements of logs barked by machinery show that the original circular section of the log had been changed to that of a circle minus 6 small segments, the area of the segments being found to be 18 per cent of that of the original circle. All logs are carefully inspected at the mill, and those in which there is evidence of decayed portions or unremoved bark are rejected. Subsequently a man removes the bark and decayed places from these imperfect logs with an ax. The logs are thrown into a large tank of hot water to loosen the ice, dirt, and sand which have adhered to them. They then pass through scrubbers, in which a powerful spray of water removes all the sand and cinders. They are then ready for the chipper. This machine consists essentially of three knife blades in a rapidly revolving vertical steel disk. One end of the log is pressed against these blades at an angle, and in a few seconds the log is reduced to chips. The resulting fragments are then run over screens to separate them into three portions. Everything that passes through a $\frac{1}{4}$-inch mesh is discarded. This chip dust is at present practically a waste product, though it is used to some extent for packing ice and for bedding horses. A half-day test at the Mechanicsville mill showed that 1,375 pounds of chip dust, or about 2.7 per cent of waste, resulted from chipping 17 cords of wood. The chips which do not pass through a 1-inch mesh are next separated and passed through a machine known as a shredder. This machine, working on a novel principle, crushes the large chips into shreds and separates the good wood from the knots to a large extent. The shredded mixture is then "floated" over a long water tank, in which the knots, by virtue of their greater specific gravity, sink to the bottom. The separation here is almost complete, and the removal of the knots at this time is of great benefit, as they interfere seriously with subsequent operations. The middle portion of the chipped mixture, which is retained on a $\frac{1}{4}$-inch screen and passes through a 1-inch screen, goes directly by belt conveyors to the storage bins over the digesters, as does also the floated portion of the shredded chips after a second screening. The chips are now ready for the digester.

THE ACID LIQUOR.

The solution of chemical reagents used in the digester to dissolve out of the wood all intercellular and other noncellulose matter consists essentially of calcium and magnesium bisulphites with an excess of free sulphurous acid. It is made by passing sulphur dioxide

through a suspension of milk of lime made from dolomitic lime, or through towers of limestone over which water is trickling. The former process is in most general use in this country. A suspension of slaked lime (milk of lime) is made, having a strength of about 1.2° B.—that is, about 1.3 per cent $Ca(OH)_2$. Gaseous sulphur dioxide is prepared either by roasting pyrite or by burning sulphur directly in specially designed burners. The gases are passed through lead pipes submerged in large tanks, through which cold water is running, as it is essential to keep the absorption apparatus as cool as possible. The cooled gas next goes into a tank of milk of lime, which is nearly saturated by allowing the gas to enter at the bottom and to bubble up through the liquid. The unabsorbed gas is conducted from the top of this tank to the bottom of a second tank filled with fresh milk of lime, where the absorption is completed. The residual gases then pass to the pumps, which maintain a partial vacuum in the tanks and insure a constant flow of gas. During absorption the contents of the tank are constantly stirred. When the acid liquor in the first tank is of the requisite strength, as shown by analysis, it is pumped into the acid storage tanks, the second tank is emptied into the first, and fresh lime is added to the second. The process of absorption is then repeated. The composition of the acid liquor varies in different mills and even in the same mill from time to time as the quality of wood varies. A specimen analysis of the liquor, expressed in the mill terms, showed free sulphur dioxide, 2.5 per cent; combined sulphur dioxide, 1.1 per cent; a total of 3.6 per cent. "Free sulphur dioxide" is the total acidity of the solution expressed as SO_2. It is therefore the free dissolved gas plus one-half the sulphur dioxide present as bisulphite. The "combined sulphur dioxide" represents the rest of the bisulphite radicle. The actual composition of the liquor is therefore as follows, the total base being regarded as calcium:

Analysis of sulphite liquor.

	Per cent.
Calcium (Ca)	0.7
Sulphur (S)	1.8
or, in combination—	
Calcium bisulphite ($CaH_2(SO_3)_2$)	3.5
Dissolved sulphur dioxide gas (SO_2)	1.4

For one charge of a digester of average dimensions, 12.8 by 34 feet, producing about 7 tons of dry pulp at each "cook," 16,000 gallons of acid liquor are used.

THE DIGESTER.

The digester consists of an upright steel cylindrical shell with a conical bottom and a nearly hemispherical top, lined with lead, within which is another lining of resistant glazed brick, pointed with a special mortar. Older forms of digesters have concrete linings. The inside dimensions of a digester of average size are, diameter 12.8 feet, total height 34 feet, and its capacity is about 2,700 cubic feet.

THE "COOK."

About 12 cords of wood chips are first placed in the digester, and then about 16,000 gallons of the acid liquor are run in, filling the digester within 6 feet of the top. The shell is then closed tightly and steam is admitted. The contents are brought rapidly to boiling temperature and then the pressure is raised gradually to about 65 pounds, two hours being consumed in this heating. During the next two hours the pressure is increased more slowly to about 80 pounds. At this point the digester is full of liquor, the water condensed from incoming steam having completely filled the space which was left at the time of filling. In order, therefore, to add more steam it is necessary to "relieve." This process consists in allowing the liquor slowly to escape from the top of the digester as steam enters at the bottom. This relief liquor is strongly acid, and as a rule is returned to the acid-liquor tanks to be used again. There is some objection to such recovery of the relief, because it is rather dark colored and is apt slightly to color the next "cook." The temperature is carefully noted and frequent analyses of the liquor within the digester are made during the "cook," especially during the last two hours. Small samples for analysis are drawn from a tap in the side of the digester near the top. They are examined for total sulphur dioxide and the color and odor are noted. If in the opinion of the attendant the reaction is proceeding too fast, the incoming steam and the relief are both shut off and the "cook" is "held." It is intended to complete the "cook" in about six hours. Nearly at that time the sulphur dioxide content begins suddenly to fall, the color becomes darker, and a peculiar characteristic odor develops. The reactions at that time are proceeding very rapidly and the charge must be blown immediately or a dark-colored stock will result. The skill of the operator is here well shown in bringing about this rather sharp end point at almost the exact time desired, six hours. A large blow-off valve is then opened at the bottom of the digester and its entire contents are blown under full pressure into the blow pit, which is a large covered wooden tank, 22 feet in diameter and 20 feet deep, provided with a large air shaft for the escape of the steam and gases. Opposite the end of the pipe leading from the digester there is a bronze baffle plate, against which the contents of the digester are thrown with great force. The pit is provided with a false bottom and the liquor is rapidly drained off. It is essential at this point to remove all the acid liquor as rapidly as possible. After the blowing the liquor darkens rapidly from a light-garnet shade to nearly black, and its retention in the pulp results in a dark-colored product. About 15,000 gallons of wash water are added as soon as possible and drained off. A second washing is then given with the same amount of water, when the

drains are closed, more water is added, and the stock is ready to be pumped to storage tanks. A small amount of the acid liquor is taken out during the "cook" as relief, but the principal part of it is discharged at the end of the "cook," constituting the sulphite pulp waste liquor.

SCREENING AND WASHING THE STOCK.

The two processes of screening and washing the stock are carried on simultaneously, and can best be described together. The stock is pumped from the blow pit into storage tanks, from which it is pumped as fast as needed into an elevated tank, flowing thence to the screens and the washing machinery. It first passes through a long revolving cylindrical screen, slightly inclined from the horizontal and provided on the inside with a continuous worm-shaped vane. This screen is very finely meshed, and its function is to remove a large part of the water from the stock. Next the stock passes into a similar cylinder with rectangular meshes about one-fourth of an inch wide and 1 inch long. The wood fiber is washed through these meshes by the aid of a stream of water playing from above. All knots and undigested chips are retained in this screen, collected at its open end, and measured, the amount and character of the undigested portions being regarded as a valuable criterion of the care with which the preceding processes have been conducted. On the average, there will be about 4 cubic feet of this material per "cook," or a little over half a foot per ton of dry pulp. The stock passes from these screens to the settling tanks or "rifflers," long troughs about 6 feet wide and 2 feet deep, provided with baffles on the bottom for the retention of sediment. The object of the tanks is to remove by sedimentation any sand or grit which may have gained access to the stock from the machinery or otherwise. The stock is now ready for the final screening, by which it is separated into marketable stock and tailings. The tailings from the first screening process are generally run through a second screen and a little good fiber is saved in that way. The final tailings are passed over a wet machine and felted into low-grade pulp, which is sold for use in the manufacture of leather board. The screened pulp also is passed over a wet machine, which is essentially a revolving screen that separates the bulk of the water from the pulp, leaving the latter in a rather thick sheet. If the pulp is to be sold or used as unbleached pulp, it is taken from the wet machine at this point, passed between large wooden rollers, and finally removed in the form of thick sheets of wet pulp. If it is to be bleached, it is removed mechanically from the rolls of the wet machine, mixed with a large volume of water, and conducted to the bleach tanks.

BLEACHING THE STOCK.

The unbleached pulp as it comes from the wet machine has a very slight brownish color, although it appears pure white to the inexperienced eye. If such pulp is made into paper, however, it is likely to darken rapidly with age and drying, so that pulp for high-grade papers must be bleached with chloride of lime. Commercial chloride of lime, or bleaching powder, consists mainly of calcium hypochlorite, and it is made by passing free chlorine gas over quicklime. The trade name, chloride of lime, is therefore a misnomer. A typical analysis, by Wagner,[a] of bleaching powder of good quality is given herewith:

Analysis of chloride of lime.

Calcium hypochlorite ($2CaOCl_2+H_2O$)	82.65
Calcium carbonate ($CaCO_3$)	.95
Calcium chloride ($CaCl_2$)	.44
Calcium hydrate ($Ca(OH)_2$)	6.80
Water (H_2O), free	9.82
	100.66

Inasmuch as the chlorine alone of the hypochlorite is available for bleaching purposes, a sample of bleaching powder having the above analysis would contain 43 per cent of "available" chlorine and would be called a 43 per cent bleach. The product on the market seldom contains so much chlorine as that, good grades in this country running from 35 to 40 per cent available chlorine.

The bleaching powder, or "bleach," as it is called in the mill, is received in large iron casks, each holding about 600 pounds. They are emptied into a mixing tank with approximately 3 gallons of water to a pound of bleach. Generally, an ordinary tank provided with a rotary agitator is used for this mixing, but at the Mechanicsville mill an improved mixer is in service, which appears to be very efficient. The tank is conical in shape, about 15 feet high and 10 feet in diameter at the top, tapering to a point at the bottom. A centrifugal pump with a 3-inch discharge is near the tank at its bottom level. This pump withdraws the liquid mixture from the bottom of the tank and discharges it horizontally into the upper part in a direction tangential to the periphery. Circulating the liquor through the tank in this manner produces an immense vortex, so that, although the liquor whirls about the sides of the tank to the level of the inlet, one can look down into this vortex almost to the bottom of the tank. This process accomplishes a thorough mixing of bleach and water in a comparatively short time. The mixture then flows into a large brick

[a] Wagner, R. von, Manual of chemical technology; trans. from 13th German ed. by Sir William Crookes, New York, reprint of 1904, p. 360.

settling tank and is allowed to settle until a clear liquor can be decanted. This liquor is tested for strength with a Baumé hydrometer and is mixed with the proper amount of a weak bleach extract to give it the required strength of about 3° B. This weaker solution is made by a second extraction of the sludge or "grout" remaining after the first decantation. The grout is usually strengthened by the addition of a small amount of fresh bleach, agitated with a fresh supply of water, and again submitted to sedimentation. The liquor obtained constitutes the weak bleach mentioned above, while the sludge remaining, the "second grout," is agitated a third time with fresh water and again settled. The third lot of supernatant liquor constitutes the water used in the first extraction of a new lot of bleach; the "third grout" is a waste product. Reference to the analysis already given will show that it consists essentially of calcium hydrate, with more or less carbonate of calcium and other impurities derived from the original lime from which the bleaching powder was prepared.

The bleach solution of about 3° B. is mixed with pulp in the proportion of about 30 gallons of solution to 100 pounds of pulp.[a] The mixture is passed successively through a series of tanks, eight in number, in which it is brought to and maintained at a temperature of about 100° F. and is mechanically stirred. Tests of this mixture are constantly being made as it passes from each tank to the next, and additional bleach solution is added as required, the processes being so regulated that, after the complete treatment, requiring about six hours' time, the pulp will be satisfactorily bleached and the bleach will be exhausted as completely as possible. It is next necessary to wash out of the pulp mixture the residual bleach and the calcium chloride resulting from the process. This is accomplished by first passing the stock under a series of washers. A washer is essentially a frame, in the form of an eight-sided prism, covered with fine-meshed copper gauze, and mounted on a horizontal axis, so that it is about half submerged in the pulp. It rotates slowly in the direction of the moving stream of stock, and as the water passes through the gauze it is collected in buckets suitably arranged within, elevated to a position above the center line of the box, and discharged through a side outlet. By this means a considerable volume of water is separated from the stock. Fresh water is admitted after each treatment and the washing is repeated several times, after which the washed stock is passed over a wet machine as previously described. It is then either pressed into sheets of wet pulp or, if it is to be used at once in the mill, is removed from the rolls by a stream of fresh water and run directly to the paper mill.

[a] All references to pulp in these processes are to the actual weight of air-dry pulp in the mixture, though the pulp is always mixed with a considerable amount of water throughout the process of manufacture.

SUMMARY.

The various processes described in the foregoing pages have been arranged for convenient reference in diagrammatic form in Plate I. The raw materials that enter into the process are shown along the top line of the diagram in capitals. They are wood, lime, sulphur (or pyrite), bleaching powder, and water. Arranged vertically at the left is a list of the waste and by-products of the process, namely, bark, sawdust, knots, sulphite waste liquor, sand and grit, and sludge or grout from the bleach-solution tanks. Much of the water used in the later processes is returned and used for washing the freshly cooked pulp, so that practically the only liquid waste is the waste acid liquor and the first wash waters, these together making up the sulphite waste liquor. At the bottom of the diagram the finished products of the process are shown, namely, low-grade unbleached pulp and bleached sulphite pulp. Disposal of the grout involves no serious difficulties. It is usually discharged into low-lying fields or into artificially constructed basins, where it is converted into compact masses of carbonate of lime. The small amount of chip dust is readily used in ice houses or as a bedding material for horses. The bark if removed at the mill is either burned or given away for fuel, though it is generally more economical to have the barking done before shipment. In the study of stream pollution, therefore, consideration need be given only to the combined waters resulting from the digestion of the chips and the subsequent washings of the pulp—that is, the liquor here called the sulphite pulp waste liquor.

SULPHITE PULP WASTE LIQUOR.

PREVIOUS INVESTIGATIONS.

This waste, arising as it does from an industry involving elaborate chemical methods and necessarily employing skilled paper-mill chemists, has probably received more careful and systematic study than any other waste product of the present day. A prize of 10,000 marks was offered in Germany in 1894 for the best method of preventing the pollution of streams by sulphite liquor, but it still remains unawarded. Scores of processes for utilizing or purifying the waste have been patented in Germany, England, and the United States, but none of them has been sufficiently successful to relieve, in any noticeable degree, the burdensome situation. Technical literature contains reports of exhaustive researches on the constitution of the organic substances found in this liquor, but there is no satisfactory agreement on this point. No more striking commentary on the difficulty of the problem can be made than the bare statement that, in spite of all these researches, the substance is still classed as a waste

product. According to Cross and Bevan,[a] who summarize a paper by H. Seidel,[b] no satisfactory application of this by-product has yet been evolved. Evaporation and combustion involve losses of sulphur.[c] A more complete regeneration of the sulphur has been the subject of a series of patents.[d] The process of V. B. Drewson[e] consists in heating with lime under pressure, yielding calcium monosulphite. The sulphite is redissolved as bisulphite by treatment with sulphurous acid. This process is relatively costly, and yields necessarily an impure lye. It has been proposed to employ the product as a foodstuff both in its original form and in the form of benzoate;[f] but its unsuitability is obvious from its composition. A method of destructive distillation has been patented. Seidel,[g] however, found on investigating the process that the yield of useful products is much too low for its economical development. Fusion with alkaline hydrates for the production of oxalic acid[h] is also excluded by the low yield of the product. The application of the liquor to tanning purposes[i] appears promising from the fact that 28 per cent of the dry residue is removed by digestion with hide powder, but this application has been investigated without practical success. Various probable uses are suggested by the viscosity of the evaporated extract, but as a substitute for glue it has proved of little value. It is also used to some extent as a binding material in the manufacture of briquets and as a substitute for gelatine in the petroleum industry. Cross and Bevan[j] and Mitscherlich[k] precipitate a compound of the lignone complex and gelatine by adding a solution of the latter substance to the sulphite waste liquors. The compound is redissolved in weak alkaline solutions and employed in this form for engine-sizing papers. Ekman has patented a process[l] for "salting out" the lignone sulphonates, the product being resoluble in water and the solution having some of the properties of a solution of dextrin. Owing to its active chemical properties this product, "dextron," has a limited capability of being substituted for dextrin. The suggestion to employ the evaporated extract as a reducing agent in indigo dyeing and printing has also proved unfruitful. Seidel's application of the soda salt of the lignone sulphonic acid as a reducing agent in chrome-

[a] Researches on cellulose, 1895–1900, p. 150.
[b] Zeitschr. angew. Chemie, 1900.
[c] German patents Nos. 74030 and 83438; also Seidel and Hanak, Mitt. Techn. Gew. Mus., 1898.
[d] German patents Nos. 40308, 69892, 71942, 78306, and 81338.
[e] German patent No. 67889.
[f] German patent No. 97935.
[g] German patent No. 45951.
[h] German patent No. 52491.
[i] German patent No. 72161.
[j] British patent No. 1548, 1883.
[k] German patents Nos. 93944 and 93945.
[l] German patent No. 81643.

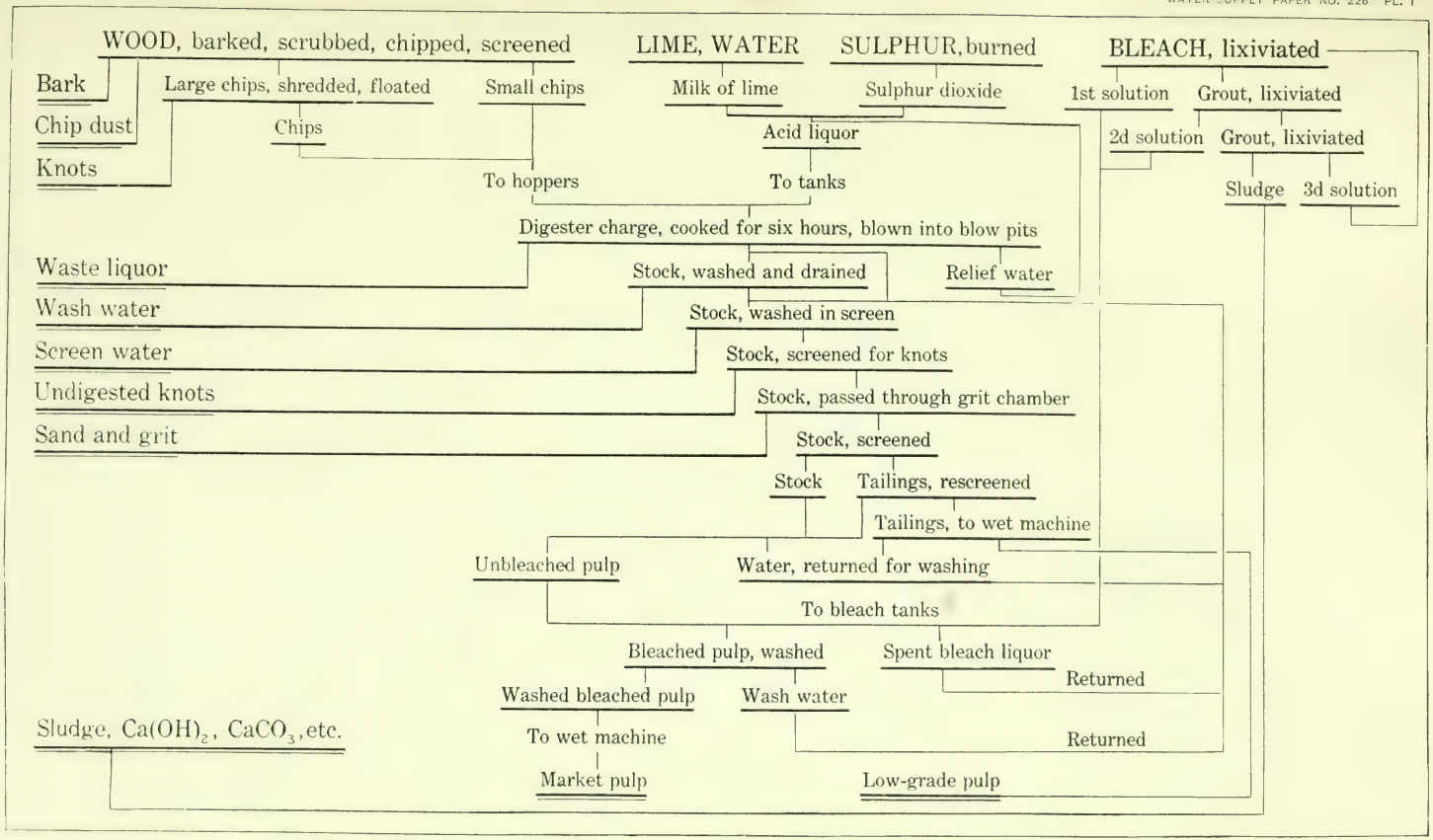


DIAGRAM ILLUSTRATING THE STEPS IN THE MANUFACTURE OF WOOD PULP BY THE SULPHITE PROCESS.

mordanting wool and woolen goods[a] is more successful in practice, and its industrial development shows satisfactory progress. The product is known as "lignorosin." In another place, however, Cross and Bevan[b] comment on this process by calling attention to the fact that such use for a by-product, produced in such enormous quantities, is of relatively small importance.

It is remarkable that the main by-product of the bisulphite process is still for the most part an absolute waste, notwithstanding the many investigations of technologists and attempts to convert it to industrial use. As it represents a percentage of the wood pulped equal to that of the cellulose obtained, it is a waste of potentially valuable material that must be termed colossal. Moreover, as a waste to be discharged into watercourses, it becomes a source of burden and expense to the manufacturer, and with the increasing restrictions on the pollution of rivers it constitutes in many localities a problem to be solved only by the cessation of the industry. The alternative in such cases is dealing with it destructively—that is, by evaporating and burning it. In this treatment the high calorific value of the organic matter appears on the credit side; but, as calcium and magnesium bisulphites are used, the residue from calcination is practically without value. If, however, a soda base is substituted, the alkali is recoverable in such form as to be directly available for the alkaline-sulphide or Dahl process. As a more complicated alternative the soda can be recovered by the old black-ash or Leblanc process, and the sulphur by the now well-established Chance process, in which lime must be added to the concentrated liquors before calcination. The engineering features of the system in respect to evaporating and calcining are the same. Economic working requires (*a*) evaporation by multiple effect and (*b*) calcining on the continuous rotary principle. For the latter process the draft of air is concurrent, by a special device, with the movement of the charge in the furnace, a feature by which a progressively increasing temperature within the furnace is procured. This interesting development has been elaborated by Drewson and Dorenfeldt, to whose publications readers who wish to inform themselves in detail in regard to these developments are referred. The present necessity of a destructive treatment of the sulphite waste liquor being assumed, their scheme has many advantages; sodium bisulphite liquors are more economically prepared and the pulp obtained is superior in paper-making quality and in economy of bleaching to that resulting from the calcium or magnesium bisulphite processes. The soda may be recovered in a form in which it is immediately available as a powerful hydrolyzing alkali in the

[a] German patent No. 99682.

[b] A text-book of paper making, 2d ed., 1900, p. 143.

manufacture of soda pulp, so that these two systems become complementary to one another. The employment of soda as the base also affords a new motive for developing the electrolytic processes of decomposing salt.

Cross and Bevan's comments present an excellent summary of conditions at the close of 1900. Significant of more recent developments in the methods of utilizing or disposing of this waste is the fact that in their second volume of "Researches,"[a] a treatise purporting to review all work of importance on cellulose industries during the years 1900–1905, these authors make no mention whatever of the sulphite waste problem.

AMOUNT OF WASTE PER TON OF PULP.

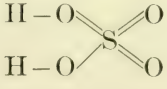
It is now practicable to inquire more carefully into the amount of the waste and its general characteristics. The important facts to be considered in any discussion of stream pollution are the amount and the character of the polluting material independent of the amount of water in which it may be carried. Chemical analyses of the waste liquor in connection with accurate determinations of its volume would furnish the requisite information, and such procedure is usually adopted. In the present case, however, it happens that the amount of polluting material bears a definite relation to the total product of the mill in pulp, independent of slight modifications of the process, whereas the amount of diluting water varies greatly in different mills and even from time to time in the same mill. For example, some mills use the old-fashioned rotary digesters, in which it is not necessary to use more than half the amount of water in the acid liquor that is used in upright digesters. The washing process is often conducted at places where water is plentiful, with a total disregard of economy in water, while in other mills strict economy of water is necessary; therefore the concentration of the waste liquors may be three or four times as great in one case as in another. In view of these facts and of the statement made above, that a definite amount of polluting material is produced for each ton of pulp turned out, it appears that the best procedure is to determine the definite relationship between the amounts of pulp and solid waste. Results obtained at one mill are applicable to any mill using a similar process, though the actual volumes of the wastes may be greatly different. After having determined this fundamental relation, it is of interest to compare the figures obtained with actual analyses of the waste liquor. Such comparison will give an approximate measure of the volume of diluting water.

[a] Researches on cellulose, 1900–1905.

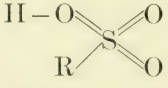
A cord of spruce wood ordinarily handled at the mill will weigh about 3,600 pounds, of which about 55 per cent, or 2,000 pounds, is actual wood substance, the remaining 45 per cent being water. The amounts of chip dust, knots, etc., which are really insignificant as compared with the total weights, may be neglected in this calculation. About 1,100 pounds of so-called "air-dry" pulp having 10 per cent water, or, roughly, 1,000 pounds of actually dry pulp, is made from 1 cord of wood. Therefore the production of 1 ton of pulp is accompanied by the production of an equal amount of waste organic material that is discharged in the waste liquor. According to the analysis on page 10, the sulphite liquor contains 0.7 per cent of calcium and 1.8 per cent of sulphur, equivalent, respectively, to 0.058 pound and 0.150 pound per United States gallon. On the basis of 16,000 gallons of acid liquor to a digester charge, which produces 7 tons of air-dry pulp, each ton of pulp is represented by 132 pounds of calcium and 343 pounds of sulphur. About 0.1 per cent of sulphur dioxide, or 9 pounds of sulphur per ton of pulp, is left unoxidized at the end of the "cook." Of the remaining 336 pounds of sulphur 10 per cent may be allowed for loss of free sulphur dioxide in the relief, leaving approximately 300 pounds of sulphur which has been oxidized in the process. The first product of this oxidation is probably sulphuric acid, according to the following equation, the oxygen being derived from the wood during the digestion:

$$SO_2 + O + H_2O = H_2SO_4.$$

This presents the simplest idea of the digestive action. Sulphurous acid is oxidized to sulphuric acid with a corresponding reduction of the wood substance. The fate of the sulphuric acid thus formed has not been satisfactorily determined. It is known that in the final product there is little free sulphuric acid. The first effect or its formation would be the precipitation of calcium sulphate, probably on the wood fibers. As magnesium sulphate is soluble, this is probably the reason why dolomitic lime gives such excellent results. If, however, all the calcium or magnesium originally used were converted to sulphate, there would be needed for that reaction only 100 pounds of sulphur, leaving still 200 pounds of sulphur unaccounted for. It will be shown when the chemical nature of the waste is considered that, according to prevailing views, the sulphuric acid from this amount of sulphur again reacts with a portion of the wood substance to form a so-called sulphonic acid. This may be regarded as sulphuric acid in which one of the OH groups has been replaced by an organic radical (R) thus:



Sulphuric acid.



Sulphonic acid.

This reaction is not complete and a small amount of sulphuric acid is generally left in the liquor. For the present it will not be necessary to discuss the relative amounts of these two acids. The waste material resulting from the digestion of sufficient wood to make 1 ton of pulp may be summarized as follows:

Materials in the waste liquor per ton of pulp.

	Pounds.
Wood material	2,000
Calcium sulphate	449
Sulphur dioxide (omitted from total)	18
Sulphur in sulphuric acid and in organic combination	196
Total solid matter	2,645

CHEMICAL COMPOSITION OF THE WASTE LIQUOR.

As has been stated, the actual strength of the waste liquor is entirely a matter of dilution. The 16,000 gallons of acid liquor used in the "cook" producing 7 tons of air-dry pulp is usually diluted with one to two times its volume of water in the blow pit, and other wash waters later mingle with this liquor in the drains. For the purpose of study, however, it is advisable to procure samples of the undiluted waste liquors directly from the digester, because in any plan for the recovery of this liquor it will undoubtedly prove advantageous to separate the undiluted liquor. For the investigation here reported samples of the liquor were collected from the bottom of the digester just before blowing. The hot liquor was drawn into a barrel, allowed to cool, and then bottled in carboys for future use. The subjoined table gives analyses of this liquor and the figures of several analyses of similar liquors by other chemists.

Analyses of sulphite pulp waste liquor.

[Grams per liter.]

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Total solids	95	82	88	85	93	92	109	52	64
Loss on ignition	82	68	75	69	81	.....	90	45	56
Ash	13	14	13	16	12	.....	19	17	8
Analysis of ash:									
Calcium (Ca)	2.2	.....	.....	.....	.....	.....	6.9	1.76	2.08
Magnesium (Mg)	1.2	.....	.....	.....	.....	.....	.18	.97	1.26
Sulphur (S)	2	.....	.....	.....	.....	.....	.....	.....	.....
Total sulphur	10.5	.....	.....	.....	.....	9.2	.....	.....	.....
Free sulphur dioxide (SO_2)	1	2.6	2.2	2.9	2.6	3.8	.....	.94	.90
Sulphite radicle (SO_3)	.....	7.3	7.9	6.7	1.2	3.8	3.8	1.10	1.36
Sulphate radicle (SO_4)	.....	4.1	5.4	4.8	2.7	1.9	7.2	[a]9.27	[a]11.10
Oxygen consumed	36	52	52	50	60	.....	.....	.....	.....
Specific gravity	.....	.....	.....	.....	.....	.....	.....	1.024	1.028

[a] Exclusive of the organic S.

No. 1, by the writer, is the average of two analyses of waste liquor collected directly from the digester at the Mechanicsville mill. Nos. 2 to 6, inclusive, are quoted by Hoffmann,[a] Nos. 2, 3, 4, and 5 being

[a] Hoffmann, C., Practisches Handbuch der Papier Fabrikation, Berlin, 1897.

by Wickelhaus,[a] and No. 6 by Lehman. No. 7 is given by Schubert,[b] and Nos. 8 and 9 are taken from the notebook of S. C. Lindberg, paper-mill chemist, who has kindly permitted their use.

These analyses give an excellent idea of the general character of the liquid. The proportions of the various constituents are in agreement with the figures which have been calculated from the amounts of raw materials used. The analyses also determine satisfactorily the nature of the inorganic matter in the waste and show the relatively large amount of organic matter present, about 80 per cent of the total solids.

CHEMICAL NATURE OF THE ORGANIC MATERIAL.

Thus far only the total amount of waste material in the liquor resulting from the digestion of 1 ton of dry pulp and its division into organic and inorganic constituents have been considered. The chemical nature and the essential characteristics of the organic matter deserve further consideration. Though our knowledge of the chemistry of wood is not extensive, the following facts seem to be definitely settled and may be accepted as embodying all that is positively known. The wood substance itself, freed from the relatively small amount of intercellular matter, such as gums and sap constituents, is a homogeneous material of fairly constant composition. To this substance chemists have given the name ligno-cellulose. Ligno-cellulose can be broken down by suitable chemical treatment into two or more substances. These are cellulose, which is the material of the wood pulp, and a complex substance or mixture variously called lignose, lignin, or lignone. It is this latter body or mixture of bodies which in the sulphite process is supposed to be sulphonated, giving rise to a substance known as lignon-sulphonic acid. The constitution of this substance is not known, nor is its chemical identity even assured. Beyond these meager facts all is hypothesis, despite the large amount of experimental work which has been done on the substance under discussion. Probably the best estimate of the character of lignone is given by Cross and Bevan,[c] who made an exhaustive study of the subject.

They conclude that it is a single substance made up of (*a*) $2C_{18}H_{18}O_{10}$, a ketone transitional to quinone which chlorinates directly to marriogallol; (*b*) $6C_5H_4O_2$, furfural, in combination by condensation with (*a*) and (*c*); and (*c*) $5C_2H_4O$, acetic residue. The simplest empirical formula for their lignone is $(C_6H_6O_3)n$, n being not less than some

[a] Papier Zeitung, 1895, No. 38.

[b] Schubert, Max, Die Cellulose Fabrikation, Berlin, 1892.

[c] Cross, C. F., and Bevan, E. J., Contributions to the chemistry of lignification: Jour. Chem. Soc., vol. 15, trans., 1889, p. 199.

multiple of 24. Tollens[a] gives as the result of his analysis of the sulphonated form the empirical formula—

$$C_{24}H_{23}O_7(OCH_3)_2.(SO_3H).$$

This formula must be slightly modified in view of Cross and Bevan's satisfactory determination of the presence of 5 acetic residues in the C_{76} molecule, instead of 6, as given by Tollens's formula. It has been stated that the chemical identity of the sulphonated form has never been satisfactorily shown. The experimental work on sulphite liquor, conducted by the author, seems to prove that the substance in question is probably not a true sulphonic acid.

PURIFICATION OF SULPHITE WASTE LIQUOR.

Investigations on the disposal of waste liquors may be carried out either with the object of recovering and utilizing the material contained therein or with the simpler aim of purifying the liquid so that it may safely be discharged into a stream. The former method of investigation has appealed most strongly to manufacturers and chemists, and a great many attempts have been made to discover some useful by-product in the waste sulphite liquors. Reference to these investigations will be made later. Owing to the failure in general of all such attempts and to the stringent laws against stream pollution, particularly in Germany, some attempts have also been made simply to purify the liquor by precipitating the organic matter, the experiments having no reference to the recovery of valuable by-products. One of the earliest of these investigations was made by H. Frank,[b] who gives the following composition of the sulphite waste which he used:

Composition of sulphite waste.

	Grams per liter.
Total solids	82
Loss on ignition	59
Ash	23
Calcium (Ca)	5.3
Magnesium (Mg)	.25
Sulphate radicle (SO_4)	14.4

In the process developed by Frank the liquor is treated first with lime to neutralize the free acid and then with chimney gases to carbonate the excess of lime and oxidize the calcium sulphite. A heavy precipitate of sulphate and carbonate is formed and it is claimed that much of the organic matter is dragged down, so that the supernatant liquid could be discharged into the stream. This process was later investigated more thoroughly by F. B. Ahrens, E. Klingstein, and P. Schubert,[c] who state that many German wood-pulp

[a] Quoted by Cross and Bevan, Researches on cellulose, p. 126.
[b] Wien. Jahresbericht, 1887, p. 1177.
[c] Zeitschr. angew. Chemie, 1895, p. 41.

mills have been compelled to close because it was found impossible to comply with the requirements of rivers-pollution officials. The examination of the waste sulphite liquor which they used showed that it gave a strongly acid reaction, had a specific gravity of 1.0465 at 15.8° C., and was optically inactive. The dry residue was 9.4 per cent, of which 1.11 per cent was ash and 8.29 per cent organic matter—not strictly accurate determinations. The liquors from the digesters were nearly neutralized by passing them over limestone. The hot lye was then mixed with a known quantity of fresh lime water once boiled, filtered, and the filtrate neutralized with carbonic-acid gas. The results obtained are shown in the following table:

Results of experiments in neutralizing hot sulphite waste liquors.

CaO added.	Analysis of supernatant liquor.		
	Dry substance.	Ash.	Organic matter.
Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
2	8.75	1.80	6.95
3	7.48	1.59	5.89
4	7.36	1.71	5.65
5	7.13	1.56	5.57
6	6.86	1.52	5.34
7	6.74	1.58	5.16
8	6.65	1.54	5.11
9	6.61	1.57	5.04
10	6.79	1.51	[a] 5.28
11	6.54	1.55	4.99
12	6.52	1.49	[a] 5.03
15	6.31	1.49	4.82
20	7.00	1.60	[a] 5.40
30	4.99	1.01	3.98

[a] Organic matter rendered soluble again by boiling.

When the liquors were treated cold, the following results were obtained:

Results of experiments in neutralizing cold sulphite waste liquors.

CaO added.	Analysis of supernatant liquor.		
	Dry substance.	Ash.	Organic matter.
Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
2	6.21	1.11	5.10
3	6.19	1.33	4.96
4	5.26	1.00	4.26
6	5.08	1.04	4.04
8	4.96	1.10	3.86
10	5.67	1.22	4.45
12	5.76	1.23	4.53
14	6.26	1.29	4.97

Sodium aluminate was also tried as a precipitant, but the results were less satisfactory. The precipitated and neutralized liquors were then treated electrically. A current of 5 amperes and only sufficient

potential was passed through the liquid between platinum electrodes, but no diminution in either mineral or organic matter was observed after two hours. A high-tension current (106 volts) was then tried, but the results were equally ineffective after a test of the same duration. It is evident, these authors conclude, that the objectionable organic matter, if removable at all, calls for some process hitherto undiscovered. Ahrens tried, unsuccessfully, to treat this waste bacterially after neutralization on the lines of his patent. It was found absolutely sterile to begin with, and the amount of bacterial filtration required for its decomposition was altogether impracticable. E. Bruch[a] found that if the waste liquors are treated when acid, or neutral, with leather glue, a compound of tannic acid and glue is formed which coagulates on storing and becomes highly viscid. If then the clear, colorless top liquor is decomposed with aluminum sulphate, another gummy precipitate is formed. Both precipitates are soluble in alkalies and in weak ammonia, and may be removed, dried, and powdered. If the clear liquor is then neutralized with chalk or lime, a precipitation and clarification ensue, and the top liquor is free from smell and has lost about 25 to 30 per cent of the total organic constituents, and these the most easily decomposable.

UTILIZATION OF SULPHITE WASTE LIQUOR.

By far the most important work on this waste liquor has had for its object the utilization of the organic matter. Its complex chemical nature and relatively large amount and the fact that it is still a chemical mystery make the field particularly inviting for research. In some interesting laboratory experiments made by Buddens,[b] and quoted by Griffin and Little,[c] the waste liquor was neutralized by ammonia, the lime was precipitated by ammonium carbonate, and the carbonate of lime thus formed was separated by filtration. The dark-brown filtrate was evaporated and the dried residue distilled. The dried residue contained 7.2 per cent of ammonia as salts. Water and a yellow oil were obtained in the condenser, and finally a crystalline sublimate appeared on the walls of the tube. The escaping gases were caught in a gasometer. The oil had at first a mercaptan-like odor, but this disappeared on heating slightly. The odor was without doubt due to organic sulphur compounds, which were present in traces. The mixture of oil and water was, after this heating, distilled with steam, the distillate was shaken out with ether and then dried, and the ether was evaporated over calcium chloride. The brown oil that remained boiled at 130° C., and as it colored a pine chip moistened with hydrochloric acid a strong

[a] Die Abwässerreinigung der Cellulose-Fabriken und die Papierleimung: Chem. Zeitung, 1892, p. 1782.
[b] Buddens, W., Papier Zeitung, March, 1891.
[c] Griffin and Little, Chemistry of paper making, New York, 1894.

carmine, it was believed to be pyrrol. Pyrocatechin was also found in the distillate, as was proved by color tests with iron salts and by the reduction of Fehling's solution. The gases from the first distillation were carbon monoxide, hydrogen, marsh gas, and hydrogen sulphide. Four hundred grams of the residue yielded 180 grams of coke, 30 liters of gas, and 200 grams of distillate. Mucic and saccharic acids could not have been present as such in the liquor, because they are formed by the oxidation of carbohydrates, and the action of the liquor is a reducing one. Yet pyrrol is formed by distilling the ammonium salts of these two acids. The only way of accounting for pyrrol is by considering that succinic acid is formed from the resins in the wood a not improbable assumption. Ammonium succinate changes readily into ammonium succinamide, which gives pyrrol when it is heated with reducing agents. The presence of pyrocatechin is due to the presence of dioxybenzoic acid (1, 3, 4), which is in the liquor as dipyrotechnic acid. The decomposition of this acid by distillation with ammonia produces tannic acid and pyrocatechin. Doctor Buddens states that there is no tannic acid in the liquor, which will give a blue-black color with ferric chloride, because the tannin in wood is reduced by digesting with sulphurous acid. The reduction is probably due to dipyrocatechuic acid, but by treating the liquor with ammonia and distilling, tannic acid is eventually formed. Sulphites are oxidized to sulphates when the tannin is reduced. It is possible, therefore, that the difficulty of pulping wood rich in tannin by the sulphite process is due to the action of the tannin, which renders the sulphurous acid ineffective. Lindsey and Tollens,[a] in their systematic search for the different sugars, used liquor from a Mitscherlich slow-process cook, with a specific gravity of 1.055, showing total solids 9.5 per cent, and calcium 0.41 per cent. The solution was pale yellow in color and strongly reduced Fehling's solution. They found no evidence of the presence of saccharose, dextrose, or dextrose-yielding sugars, traces only of levulose or levulose-yielding sugars, and but a small amount of galactose. On the other hand, mannose, determined as a hydrazine, was found to represent 6 to 7 per cent of the original total solids. Furfural was found in some quantity on heating with hydrochloric acid, and xylose was identified in the solution. Alcoholic fermentation of the liquor gave amounts of alcohol corresponding to only 1.2 per cent of the total carbohydrates. The remaining gummy mass behaved as a homogeneous complex, yielding several synthetic preparations, the analyses of which were consistent with the view of its homogeneity.

[a] Liebig's Annalen, No. 267, 1892, p. 341. Abstracts Jour. Chem. Soc., 1892, p. 802.

A summary of various attempts to recover valuable products from the waste has already been given (pp. 15–18). Thus far no satisfactory recovery of valuable chemical substances has been made. The substance itself has been used as a substitute for glue and for sizing. Mitscherlich precipitated the tannin compounds with glue in the presence of alum and sulphuric acid, obtaining a rubbery mass, soluble in weak alkali, which could be used in engine sizing. He later improved the process[a] by precipitating with lime to remove the sulphite present and then diffusing the liquor through membranes. The diffusible portion contained sugars and was fermented for alcohol. The nondiffusible part was treated as described above in order to remove the tannins. A later patent[b] describes a process in which, after the removal of the calcium salts, the liquor is heated with hair or bone to give a semiwaterproof sizing. V. Drewnen and L. I. Dorenfeldt[c] treat the liquor with soda ash recovered from the soda pulp process, precipitating the lime and a part of the organic matter. They draw off the clear liquor and burn the residue, using the heat of the combustion to evaporate more liquor. The liquor is said to contain more calorific energy than is necessary to evaporate it. The soda ash is recovered from the residue by the usual process, and about 60 per cent of the sulphur is recovered by liberating free sulphur dioxide with carbon dioxide gas. The fumes and the gases from the evaporation were found to be very corrosive. This trouble was finally overcome by combining the wastes of the sulphite and soda pulp mills and treating them like soda wastes. Frank's process, as described by Schubert,[d] consists in precipitating the remaining calcium bisulphite as normal sulphite with excess of lime, after which the precipitate is redissolved in an excess of sulphur dioxide. Such treatment would recover only a small part of the total sulphur. Meyer's process, also described by Schubert,[e] seeks to recover valuable products by destructive distillation of the organic material in the waste. The liquors are neutralized, concentrated to a thick sirup, mixed with charcoal to a paste, and distilled. The yield of valuable products is too small to make the process economical. H. Seidel has employed the soda salt of the lignone sulphonic acid as a reducing agent in chrome mordanting wool, where, under the name "lignorosin," it is used in place of tartaric and lactic acids.[f] The material, especially when concentrated, is very sticky, and many attempts have been made to utilize it as a substitute for glue. In J. S. Robe-

[a] United States patent No. 681241, 1901.

[b] United States patent No. 687844, 1901.

[c] United States patents Nos. 620755, 1899, and 726036, 1902.

[d] Schubert, Max, Die Cellulose Fabrikation, Berlin, 1892.

[e] Op. cit.

[f] Rev. gén. des mat. col., vol. 2, 1898, p. 370. Jour. Soc. Chem. Ind., vol. 17, 1898, p. 1043. British patent No. 19005, 1897. German patent No. 99682, 1897.

son's process[a] for the manufacture of an adhesive, which is being used at Ausable Forks, N. Y., by a large mill,[b] the waste liquor is neutralized with lime and evaporated in vacuo. The product is a thick, molasses-like fluid, which finds application in foundries as an adhesive in core making. C. H. Voight[c] makes a glue substitute by heating starch and a peroxide with the sulphite liquor. A. G. Brooks[d] evaporates the liquid till it contains 20 per cent water, then adds carbohydrates or albuminoids and dries the mass, which is used for fuel, pitch, glue, resin, or size. Knoesel[e] concentrates to 25° B. and treats with a slag meal high in phosphorus (Thomas slag). It is claimed that the phosphorus of the slag is rendered soluble in citrates and becomes available in fertilizing. Ahrens[f] investigated the process and could not substantiate its claims. Processes have been proposed for the destructive distillation of the substance, and, as has already been stated, both pyrrol and pyrocatechin have been obtained in this manner. The yield of these products has not been sufficient to make the process successful. Patents have been granted for processes involving the use of the liquor in tannin.[g] According to Seidel[h] 28 per cent of the solids are removed by rawhide powder. No satisfactory method has yet been described for separating the tannin substance from the remainder. This seems to be one of the important lines for future investigation. Morterad[i] subjects the hot liquors to a partial vacuum and removes from them a considerable volume of sulphur dioxide. Bergerhopf[j] made a cheap grade of paper for newspapers by using the waste liquors to digest sawdust. Eckman[k] "salts out" the liquors and makes a concentrated solution, which he calls "dextrone," a substitute for dextrin, or British gum.

EXPERIMENTAL INVESTIGATIONS WITH THE ORGANIC MATERIAL.

The knowledge of the chemical reactions which characterize lignone is very meager. Early in the present study it was deemed important to obtain additional light on the general behavior of this material. It was hoped that in this way knowledge of its chemical nature might be enlarged and particularly that some reactions of industrial value

[a] United States patent No. 833634, 1906.
[b] Paper Trade Journal, Jan. 5, 1905, p. 12.
[c] United States patent No. 770202, 1904.
[d] British patent No. 8088, 1901.
[e] Jour. Soc. Chem. Ind., 1902, p. 489.
[f] Chem. Zeitung, vol. 4, 1905, p. 40. Chem. Centralbl., vol. 1, 1905, p. 700. Jour. Soc. Chem. Ind., vol. 14 1905, p. 343.
[g] German patent No. 72161.
[h] Zeitschr. angew. Chemie, 1900, p. 951.
[i] United States patent No. 833936, 1906.
[j] German patent No. 160651, 1903. Jour. Soc. Chem. Ind., vol. 24, 1905, p. 1028.
[k] German patent No. 81643.

might be discovered. For this study preparations of the dry material were made in various ways; the solubility of these preparations was investigated; attempts were made to identify a sulphonic acid in the material; and various other reactions were studied.

PREPARATION OF CRUDE "LIGNONE."

Three different preparations of the dry material were used. "Lignone A" was obtained in dry form at the mill. It was observed that certain steam pipes passing near the blow pit were heavily coated with a hard vulcanite-like substance, nearly an inch thick in places. About a pound of this material was chipped off and used in certain of these experiments. "Lignone B" was the supposed calcium compound obtained by evaporating the liquor to one-half volume and salting out with common salt. A granular amorphous substance, containing some salt and moisture, was obtained. "Lignone C" was supposed to be the sodium compound. When the liquor was neutralized with sodium carbonate and allowed to settle, a large amount of calcium carbonate was precipitated. The remaining liquor was evaporated and salted.

SOLUBILITY OF CRUDE "LIGNONE."

The solubility of each of these preparations was tested with several solvents in an endeavor to obtain a liquid from which the material could be crystallized. No solution took place in either hot or cold benzoin, amyl alcohol, allyl alcohol, petroleum ether, amylene, amyl acetate, aniline, toluene, xylene, nitrobenzene, carbon bisulphide, ethyl ether, or benzol. Benzoin seemed to soften the substance. The tests were repeated after acidifying to see if a free acid could be found which would dissolve, but the results were again negative. The two alcohols dissolved the samples if diluted with water. Ordinary ethyl alcohol also dissolved it, a result probably due to the water present. Absolute ethyl alcohol was not tried.

REACTIONS WITH PHOSPHORUS CHLORIDES.

An important general reaction of sulphonic acids is that with phosphorus pentachloride, giving sulphon-chlorides according to the reaction—

$$R.SO_2.OH + PCl_5 = R.SO_2.Cl + POCl_3 + HCl.$$

Sulphon-chlorides are for the most part insoluble oils which combine with ammonia to form crystallizable sulphonamides, as follows:

$$R.SO_2.Cl + 2NH_3 = R.SO_2.NH_2 + NH_4Cl.$$

Appropriate mixtures of the crude "lignones" with varying amounts of the pentachloride, the oxychloride, and mixtures of the two were made. No indication of any reaction was obtained at room tempera-

ture or at temperatures up to 180° C., at which point the oxychloride begins to distill. Altogether about twenty attempts were made to bring about this reaction. The products after heating were treated with ammonia, but no evidence of any amide was ever obtained. It must be concluded, therefore, that the "lignone" does not react with the chlorides of phosphorus in the way which characterizes sulphonic acids in general.

FUSION WITH ALKALI.

Another characteristic of sulphonic acids is their ready reduction to corresponding phenols on fusion with caustic alkali according to the reaction—

$$R.SO_2.OH + 2KOH = K_2SO_3 + R.OH + H_2O.$$

Preparations of "lignone" were fused in this way, the resulting masses being extracted with ether and evaporated. Only mere traces of ether extract were obtained, and these gave none of the usual tests for phenols. During the fusion the sulphur gave strong evidence of its escape into the air in the form of some volatile mercaptan, with a very penetrating and sickening odor.

POSITION OF THE SULPHUR IN "LIGNONE."

As in both series of tests just described the "lignone" failed to react in a way characteristic of true sulphonic acids, the presumption is reasonable that a sulphonic acid is not present. An interesting question is therefore raised. How is the sulphur in this material related to the molecule? In the salting-out experiments some light was thrown on this question. It was found that a considerable part at least of the sulphur was in such loose combination that it was given off as sulphur dioxide in the cold during the salting process. The result when first observed was attributed to the sulphur dioxide in the liquor, but it was possible to show that such was not its origin. A small amount of the fresh liquor was cautiously evaporated nearly to dryness and then diluted with water to the original volume. This solution was then salted in parallel with a fresh solution. As nearly as could be determined by the sense of smell, equal amounts of sulphur dioxide were given off by both samples. Confirmatory results were obtained by dissolving some of "lignone A," a completely dried sample, and treating it in the same manner. That all the sulphur could not be removed by this procedure was evident on drying and igniting the salted sample, when the same disgusting odor was given off as by the original sample and apparently to the same degree. This point was verified quantitatively by titration with

iodine solution. When the solution was acidified, an evolution of sulphur dioxide occurred and the reducing power increased from an equivalent of 0.01 per cent to 0.104 per cent of sulphur dioxide. On continued boiling without acid the reducing power increased from 0.011 to 0.015 per cent of sulphur dioxide. Boiling with potassium hydrate still further increased it to 0.201 per cent. Lime water had a similar but less marked effect. All these observations point to the probable fact that a sulphurous ether is present. Such ethers yield sulphur dioxide to sulphuric acid and are readily hydrolyzed by an alkali. The results here obtained are, in all respects, what would be expected from sulphurous ether, and the presence of a sulphonic acid has not been verified. Though the presence of the latter compound has not been disproved, the writer is strongly of the opinion that the major part, at least, of the sulphur is present in the form of an acid sulphurous ether of some complex hydrocarbon radicle.

REACTIONS WITH AROMATIC AMINES.

Previous investigators have generally agreed that "lignone" possesses aldehydic properties. A characteristic property of aldehydes is that of forming condensation products with certain bodies; the aldehyde and the other substance—aniline, for example—condense to form a complex molecule. When a solution of "lignone" was mixed with aniline, a bright-red precipitate was formed. An excess of aniline changed this body to a black insoluble gum. The reaction took place equally well with aniline oil or with aniline sulphate. All attempts to purify the product failed. It was insoluble in all solvents except acids, which apparently decomposed it into its original constituents. Reference will later be made to the action of strong nitric acid on the gum. Exactly similar condensations were observed with the following: Ethyl aniline, diethyl aniline, dimethyl aniline, methyl diphenylamine, *m*-chloraniline, *p*-chloraniline, dichloraniline (1–2–4), *m*-nitraniline, *p*-nitraniline, *o*-toluidine, *p*-toluidine, dibrom-*o*-toluidine, *o*-tolidine. Substituted amines which did not give condensations were *o*-nitraniline and dinitraniline (1–3–5). Bright-red products were formed in every case where the amine retained the NH_2 group. With amines in which substitution had taken place in that group brown or black compounds were formed. The reactions of these preparations with fused sodium sulphide is considered under the caption "Sulphur dyes." As in the case of the aniline condensation product, it was not possible to purify these gummy substances. They were decomposed into the original constituents on treatment with strong acids or generally on heating.

REACTIONS OF THE AMINE CONDENSATION PRODUCTS WITH NITROUS ACID.

On the assumption that the condensation products still retain their characteristic amine group, they were treated with nitrous acid in an ice bath, in the hope of obtaining some new bodies through the diazo reaction. In the case of aniline this reaction is—

$$C_6H_5NH_2.HCl + NO_2H = C_6H_5N:NCl + 2H_2O.$$

When this substance alone is heated it decomposes, yielding phenol, but in the presence of other substances, such as some unaltered aniline, reactions of technical importance can be brought about:

$$C_6H_5N:NCl + H_2O = C_6H_5OH + N_2 + HCl,$$

or $$C_6H_5N:NCl + NH_2C_6H_5 = C_6H_5N:N.NHC_6H_5 + HCl.$$

The product of the latter reaction is diazo-amidobenzene, a starting point for the preparation of an important group of dyes. Application of the diazo reaction to the condensation products above described did not generally result in apparent change. In some experiments an excess of the amine reacted in a manner quite characteristic of the amine itself without any substituted groups. The general inertness of these bodies under such conditions leads to the conclusion that substitution takes place in the amido group of the condensation products. This is further verified by the fact previously shown, that all primary amines gave bright-red condensation products, while the others gave brown or black substances.

REACTIONS WITH NITRIC ACID.

Concentrated nitric acid was found to have a very vigorous action on the dry "lignone" preparation and on the sulphite liquor itself at high temperatures. The organic matter of the dry "lignone" is completely oxidized, chiefly to oxalic acid, in the presence of a sufficient excess of the acid. Nitrous acid fumes are evolved, and the odor of acetic acid can be distinctly detected. The action of nitric acid on the waste liquor is less violent. When a mixture of one part strong acid and ten parts of liquor is warmed, action begins at once. Nitrous and acetic acids are evolved, as with the dry product, and the color of the solution changes from dark brown to bright, golden orange. This solution, after neutralization of the free nitric acid by an excess of sodium acetate, was found to dye wool and silk a beautiful orange-yellow. This yellow dyestuff, which for convenience may be called lignone yellow, is of peculiar interest as a product to be recovered that may be valuable, and it was therefore carefully studied.

LIGNONE YELLOW.

Difficulty was at first experienced in separating the dye from the liquid. Cloth could be dyed directly in the liquid with excellent results, but on evaporation the dye lost a great deal of its coloring power. By evaporating it in partial vacuum to a thick sirup and then reducing it to dryness in a warmed vacuum desiccator, it was finally possible to obtain the desired material in dry form. It is a light-yellow powder, very porous, and extremely hygroscopic, which latter property considerably diminishes its commercial value.

Samples of woolen cloth dyed in baths prepared from the dried material in the proportion of 2 per cent of the dye, by weight, were very beautifully colored. The color is retained on boiling for half an hour in soap solution, dilute acetic acid, or dilute alkali. It withstands the action of bleaching powder, chromate, and other oxidizing agents. It will stand direct summer sunlight for two days without apparent discoloration, but it is affected on the third day; so it is, therefore, only moderately fast to sunlight.

Lignone yellow is exceedingly soluble in water and in ethyl alcohol. On evaporation of these solutions it yields a pasty mass which is completely dried with difficulty. When dried at 100° C., it is decomposed with evolution of nitrous oxide. It can be eventually oxidized with nitric acid to oxalic acid. From the manner of its formation it might be thought to be a nitro-body and in its dyeing properties it resembles picric acid; but it differs from the latter and from other nitrophenols in several particulars. Picric acid, or tri-nitrophenol, crystallizes from hot water and is difficultly soluble in cold water. The same is true of para-nitrophenol. Ortho- and meta-nitrophenols melt at 45° C. and 96° C., respectively. The three dinitrophenols are converted to picric acid on further nitration. If lignone yellow is an aromatic nitro-body, it must be more complex than any of the nitrophenols. Repeated attempts to reduce this dye were made, but no amido-body could be detected after attempted reduction with zinc dust, zinc and hydrochloric acid, iron and sulphuric acid, ammonium sulphide, hydrogen sulphide, or the electric current. In no case did nitrous acid bring about any reaction after these attempts at reduction. Generally, the yellow color was not destroyed. Neither weak chromic acid nor bleaching powder destroy the color. Long-continued boiling of the original sulphite liquor with sodium nitrite gives a liquor with feeble dyeing properties, the color being like that of the nitrated substance. It is possible, therefore, that the dye is a nitroso-compound of some complex radicle rather than a nitro-body. All attempts to prove this point resulted negatively and the question of the fundamental character of the dye remains open.

REACTIONS OF THE AMINE CONDENSATION PRODUCTS WITH NITRIC ACID.

It was thought that the nitration of the substances produced by the condensation of the "lignone" substance with various amines might give rise to dyes of different character, and that the latter might have technical value as well as furnish some clue to the nature of lignone yellow. Accordingly, the different condensations described under "Reactions with aromatic amines" (p. 30) were submitted to the action of dilute nitric acid and the dyeing properties of the resulting solutions were tested on samples of wool. To obtain comparative results, the same quantities of the various components were used each time. As many of the amines are themselves capable of easy nitration under suitable conditions, a blank test was made each time, the amine tested being used without any sulphite liquor. The results of such blank tests as gave a dye in any way similar to that resulting from the condensation product are not recorded as positive. In each test approximately one part of the amine and one part of nitric acid were used with twenty parts of the sulphite liquor. The results of the tests are summarized in the following table:

Nitration of products resulting from the condensation of "lignone" and amines; wool dyed in resulting liquors.

Amine.	Color of dye produced.	Intensity of color.	Color of blank.
Aniline	Golden yellow	Strong	Colorless.
Dimethyl aniline	Dark yellow	Strong	Yellow.
Ethyl aniline	Olive green	Strong	Olive brown.
Diethyl aniline	Greenish yellow	Weak	Colorless.
Methyl diphenylamine	Lemon yellow	Weak	Brown.
m-Chloraniline	Red, washing out yellow	Weak	Pale pink.
p-Chloraniline	Reddish orange	Strong	Colorless.
Dichloraniline	Reddish brown	Strong	Pale orange.
o-Nitraniline	Golden orange	Strong	Colorless.
m-Nitraniline	Golden orange	Strong	Colorless.
p-Nitraniline	Dark orange	Strong	Colorless.
Dinitraniline	Canary yellow	Weak	Colorless.
o-Toluidine	Golden yellow	Strong	Colorless.
p-Toluidine	Dark orange	Strong	Colorless.
Dibrom-*o*-toluidine	Golden orange	Strong	Colorless.
o-Tolidine	Brownish yellow	Strong	Purple.

With the exception of one or two doubtful cases, it appears that the condensation products enter into reaction with nitric acid just as "lignone" alone does, and that the shade and intensity of the dyes produced by the reaction vary from green through orange and yellow to brown, depending on the nature of the amine that is used. Some general observations can also be made from this study. Substitution in the amido group of ethyl aniline, etc., gives greenish shades, and the lighter the substituting groups the more pronounced the green. In mono-substituted aniline, the para-compounds give the most bril-

liant and powerful dyes, and then in decreasing brilliancy the meta- and the ortho-compounds. The most powerful and brilliant dyes of the series in the table were those produced by *p*-chloraniline, *p*-nitraniline, and *p*-toluidine. Chlor-compounds give the most brilliant dyes; the nitro-compounds give dyes of more strength and body. As with the nitrated "lignone" alone, here also every attempt failed to produce amines from their nitrated substances. Many of the products, it is true, gave a reaction with nitrous acid after reduction, but in all such cases the reaction was that of the amine originally used and the resulting substances could be prepared equally well without the addition of "lignone." Reduction of the nitraniline products was not attempted, as too great complication would arise from the presence of the nitro-groups known to be present.

SULPHUR DYES.

Many organic substances yield dyes when fused with a mixture of sulphur and sodium sulphide. These so-called sulphur dyes are now manufactured in a variety of colors. They are direct cotton dyes—that is, they dye cotton without the aid of a mordant—and they are very fast. Their cheapness and valuable properties have caused them to come into wide use. An attempt was made to prepare dyes of this kind from sulphite waste liquor and from several of its condensation products. In particular, it was hoped to obtain dyes of bright color, red or blue, because such colors are especially desirable and bring good prices on the market. Brown and black are much more readily made, and are consequently cheaper. Mixtures of one part dry crude "lignone" and one-half part each of sodium sulphide and sulphur were fused for fifteen minutes at a low heat. The resulting mass was extracted in hot water and the extract filtered and evaporated. From 25 grams of dry "lignone" there were made 20 grams of a green powder, soluble in water containing a little sodium sulphide. This powder was found to be a true sulphur dye, coloring cotton a dark green, which changed to a good black on oxidation in the air or on subsequent treatment in a chrome bath. Compared with commercial dyes in the market, this dye is worth about 7 cents a pound in its impure condition. About half its weight is inert material, which can be removed by proper treatment. Similar experiments in preparing sulphur dyes were made with the condensation products previously mentioned. (See p. 33.) The shades of the resulting dyes were somewhat modified by the presence of the amine, but they were all browns, grays, or black. No advantage was apparent in the use of the condensed products over that of the untreated "lignone."

COMMERCIAL POSSIBILITIES OF LIGNONE DYES.

Two of the best dyes, namely, those resulting from the nitration of "lignone" alone and of "lignone" condensed with *p*-chloraniline, were prepared in large quantity, in order to determine the yield and the cost of the process. One hundred grams of dry crude "lignone" were treated with 50 cubic centimeters of concentrated nitric acid (specific gravity 1.42), and the resulting solution evaporated in vacuo. Seventy grams of lignone yellow were obtained. Compared with mandarin yellow, the technical dye approaching it most nearly in color and fastness, it is worth 18 cents a pound. The cost of nitric acid would be 5 cents a pound of dye. To neglect for the moment the cost of evaporating the original liquor, the margin between the cost of the acid and the value of the dye appears to be sufficient to pay for the work of handling. This would be true at places where expediency makes it necessary to evaporate the liquor in any case, and also at places where the dye could be used in liquid form as made. The cost of evaporating the liquor, however, would undoubtedly be greater than the value of the dye. It must also be borne in mind that there is necessarily a limited market for a dye of this kind—a market too limited, in fact, to permit any general adoption of this plan of utilization, even if it were very much cheaper. A similar test of the cost, yield, and value of the dye from *p*-chloraniline gave an additional cost of 9 cents a pound of dye for aniline, making the total cost for material 14 cents a pound. While the color was much more brilliant, its red shade lowers slightly its market value, pure yellows and greenish yellows being in much greater demand for use than browns. As an additional market outlet, however, this dye may possibly help in the utilization of sulphite waste liquor. The actual results attained in this investigation are not considered so important as the fact that a new and interesting series of reactions of "lignone" have been discovered. Further development of these dyes is the work of the skilled expert in textile coloring. It is not too much to expect that such an expert, possessing full knowledge of the technique of dyeing, will be able not only to simplify and to reduce to a practical working basis the methods herein outlined, but also to discover new and more valuable products by further experimentation along similar lines.

CONCLUSION.

The foregoing study of sulphite pulp waste liquor and of the possible utilization of the organic material in it may be summarized in a few sentences.

Stream pollution by the waste from sulphite pulp mills is extensive and wasteful; every year over two and a half billion pounds of solid

matter from this source are turned into the rivers and lakes of the United States.

The problem of utilizing this immense amount of waste matter has been studied for a long time, and numerous processes for using or for destroying it have been devised, but they are all unsuccessful, either because there is only a limited market for the proposed product or because the suggested process is prohibitively costly.

Successful disposal of the sulphite waste liquor lies obviously in the utilization of the so-called "lignone" in it, but aside from the employment of this substance to a slight extent as an adhesive and as a source of tannin, no practicable way for its direct use has been devised.

The waste consists principally of wood material separated from the wood fiber by the action of a strong sulphite solution on wood chips; it is a compound of "lignone" with sulphur; but the exact nature of the union has not been definitely demonstrated.

Experimental evidence indicates that the sulphur-bearing compound in the waste liquor is not a true sulphonic acid; at all events, it does not react like an ordinary sulphonic acid. Its condensation with the aromatic amines point to its probable aldehydic nature.

Nitration of "lignone" and of its amine condensation products gives a series of dyes the shade and intensity of which vary from green through orange and yellow to brown, depending on the nature of the amine that is used. These substances dye wool directly, giving brilliant colors that are fast to soap, acids, and alkalies, and reasonably fast to sunlight. One of them, named lignone yellow, and made by nitrating crude "lignone" itself, dyes wool and silk a beautiful orange yellow. Fusion of "lignone" with sodium sulphide and crude sulphur produces a sulphur dye that colors cotton dark green, changing to black on treatment in a chrome bath.

A search for new compounds, such as that made in the present investigation, possesses the serious drawback that much time and effort may be spent without tangible results; on the other hand, an important discovery may be made at any time. Certain reactions brought to light in this work with "lignone" reveal great possibilities. Though the dye called lignone yellow has only slight commercial possibilities and is at best but a partial solution of the major problem, yet the opportunities for further progress along this line are pregnant with the ever-present chance of discovering valuable substances. The number of "lignone" condensation products is almost unlimited, and a wide field for investigation is thereby offered. Only a small portion of a large and interesting territory has been covered by these experiments and the results are by no means conclusive. But it is hoped and expected that the mere reopening of this old and practically abandoned problem by calling attention to these new lines of attack may result in renewed investigation and in the ultimate utilization of a substance that to-day is probably the most valuable waste material known to industrial chemistry.

SURVEY PUBLICATIONS ON STREAM POLLUTION.

The following water-supply papers of the Survey discuss stream pollution. Nos. 103, 152, 185, and 194 can be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at the prices stated. Any of the others will be sent free, while the edition lasts, on application to the Director of the United States Geological Survey.

72. Sewage pollution in the metropolitan area near New York City and its effect on inland water resources, by M. O. Leighton. 1902. 75 pp., 8 pls.
79. Normal and polluted water in northeastern United States, by M. O. Leighton. 1903. 192 pp.
103. A review of the laws forbidding pollution of inland waters in the United States, by E. B. Goodell. 1904. 120 pp. 10c. (See No. 152.)
108. Quality of water in the Susquehanna River drainage basin, by M. O. Leighton, with an introductory chapter on physiographic features, by G. B. Hollister. 1904. 76 pp., 4 pls.
113. The disposal of strawboard and oil-well wastes, by R. L. Sackett and Isaiah Bowman. 1905. 52 pp., 4 pls.
121. Preliminary report on the pollution of Lake Champlain, by M. O. Leighton. 1905. 119 pp., 13 pls.
141. The normal distribution of chlorine in the natural waters of New York and New England, by D. D. Jackson. 1905. 31 pp., 5 pls.
152. A review of the laws forbidding pollution of inland waters in the United States (second edition), by E. B. Goodell. 1905. 149 pp. 10c.
179. Prevention of stream pollution by distillery refuse, by Herman Stabler. 1906. 34 pp., 1 pl.
185. Investigations on the purification of Boston sewage, by C.-E. A. Winslow and E. B. Phelps. 1906. 163 pp. 25c.
186. Stream pollution by acid-iron wastes, a report based on investigations made at Shelby, Ohio, by Herman Stabler. 1906. 36 pp., 1 pl.
189. The prevention of stream pollution by strawboard waste, by Earle B. Phelps. 1906. 29 pp., 2 pls.
192. The Potomac River basin—geographic history; rainfall and stream flow; pollution, typhoid fever, and character of water; relation of soils and forest cover to quality and quantity of surface water; effect of industrial wastes on fishes; by Bailey Willis, R. H. Bolster, H. N. Parker, W. W. Ashe, and M. C. Marsh. 1907. 364 pp., 10 pls.
193. The quality of surface waters in Minnesota, by R. B. Dole and F. F. Wesbrook. 1907. 171 pp., 7 pls.
194. Pollution of Illinois and Mississippi rivers by Chicago sewage; a digest of testimony in the case of the State of Missouri *v.* the State of Illinois and the Sanitary District of Chicago, by M. O. Leighton. 1907. 369 pp., 2 pls. 40c.

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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

WATER-SUPPLY PAPER 227

GEOLOGY AND UNDERGROUND WATERS OF SOUTH DAKOTA

BY

N. H. DARTON

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CONTENTS.

	Page.
Introduction	7
Geography and topography	8
Geology of the Black Hills region	8
General relations	8
Cambrian system	10
Deadwood sandstone	10
Ordovician system	11
Whitewood limestone	11
Carboniferous system	11
General outline	11
Englewood limestone	12
Pahasapa limestone	12
Minnelusa sandstone	13
Opeche formation	14
Minnekahta limestone	14
Triassic (?) system	15
Spearfish formation	15
Jurassic system	16
Sundance formation	16
Unkpapa sandstone	17
Cretaceous system	17
Morrison shale	17
Lakota sandstone	18
Minnewaste limestone	18
Fuson formation	19
Dakota sandstone	20
Benton group	20
Graneros shale	20
Greenhorn limestone	21
Carlile shale	21
Niobrara formation	22
Pierre shale	22
Fox Hills sandstone	24
Tertiary system	24
White River group	24
Geology of south-central South Dakota	26
General relations	26
Tertiary deposits	26
Geology of northwestern South Dakota	27
General outline	27
Fort Union, Laramie (?), and Fox Hills formations	28
Post-Eocene	31
Geology of eastern South Dakota	32
General structure	32
Archean and Algonkian rocks	33
Paleozoic to Jurassic	40

Geology of eastern South Dakota—Continued. Page.
Cretaceous system 41
Dakota sandstone 41
Benton group 48
Niobrara formation 53
Pierre shale 56
Fox Hills sandstone 58
Tertiary deposits 58
Quaternary deposits 58
Underground waters 59
General conditions 59
Water horizons 61
Dakota and associated sandstones 61
Sandstones of the Benton group 62
Minnelusa sandstone 62
Fox Hills and overlying sandstones 63
Deadwood sandstone 63
Chadron formation 63
Deep wells and well prospects in South Dakota 64
Introductory statement 64
Aurora County 65
Beadle County 68
Bonhomme County 69
Brookings County 72
Brown County 72
Brule County 74
Buffalo County 75
Butte County 76
Belle Fourche and vicinity 78
United States Reclamation Service 79
Orman well 80
Chambers ranch 81
Vale 81
Campbell County 81
Charles Mix County 82
Cheyenne Indian Reservation 84
Clark County 85
Raymond 85
Clark 86
Clay County 86
Codington County 87
Custer County 87
Davidson County 89
Day County 90
Andover 91
Pierpoint 91
Webster 91
Deuel County 92
Douglas County 92
Edmunds County 92
Fall River County 94
Edgemont 95
Minnekahta 99
Ardmore 100

Underground waters—Continued. Page.
Deep wells and well prospects in South Dakota—Continued.
Fall River County—Continued.
Argentine 100
Hot Springs 101
Faulk County 101
Grant County 102
Gregory County 103
Hamlin County 104
Hand County 104
Hanson County 106
Hughes County 108
Hutchinson County 109
Hyde County 111
Jerauld County 112
Kingsbury County 113
Lake County 117
Lawrence County 118
Lincoln County 118
Lyman County 119
Wells opposite Chamberlain 119
McClure well 120
Capa 120
Kennebec 121
Vivian 121
Draper 121
Murdo McKenzie 121
McCook County 122
McPherson County 122
Marshall County 123
Meade County 124
Wells north of Sturgis 124
Fort Meade 125
Miner County 126
Minnehaha County 127
Moody County 127
Pennington County 128
Pine Ridge Indian Reservation 128
Potter County 130
Roberts County 131
Rosebud Indian Reservation 131
Sanborn County 133
Spink County 136
Standing Rock Indian Reservation 138
Stanley County 138
Wendte 139
Nowlin 139
Sully County 140
Turner County 142
Union County 142
Walworth County 143
Yankton County 143
The construction and management of artesian wells 146
Index 151

ILLUSTRATIONS.

		Page.
PLATE I.	Geologic map of South Dakota	In pocket.
II.	Columnar sections of Black Hills, etc	8
III.	*A*, Deadwood sandstone in northern part of Deadwood; *B*, Lakota sandstone lying unconformably on Unkpapa sandstone, Sheps Canyon	10
IV.	*A*, Top sandstone of Minnelusa formation west of Sturgis; *B*, Minnekahta limestone west of Hermosa	14
V.	Greenhorn limestone southwest of Edgemont	20
VI.	Cross sections of South Dakota	24
VII.	Chadron and Brule formations, Big Badlands	26
VIII.	*A*, Central portion of Big Badlands, Cottonwood Draw; *B*, South end of Sheep Mountain, showing volcanic ash bed	28
IX.	*A*, Upper member of White River group, Wounded Knee Creek; *B*, Lignite beds at south end of North Cave Hill	30
X.	Map showing contour of bed-rock surface in eastern South Dakota	32
XI.	Map showing artesian conditions	In pocket.
XII.	Map of South Dakota, showing relative volumes of flows from wells	64
XIII.	Map showing structure of Dakota sandstone	66
XIV.	Artesian well northwest of Mitchell	90
XV.	Artesian well at Woonsocket	134
FIGURE 1.	Columnar section of water horizons	59
2.	Apparatus illustrating declivity of head of liquids flowing from a reservoir	60
3.	Diagram of South Dakota, showing hydraulic gradient by contour lines of "head"	61
4.	Hydraulic gradient in eastern South Dakota	61
5.	Section from Black Hills to Pine Ridge across Fall River County	94
6.	Map of Hanson County, showing artesian conditions	106
7.	Diagram illustrating the escape of water from a lower into a higher horizon in a well	148

GEOLOGY AND UNDERGROUND WATERS OF SOUTH DAKOTA.

By N. H. Darton.

INTRODUCTION.

This report is intended mainly to set forth the geologic conditions bearing on the occurrence of artesian waters in South Dakota. It comprises a description of the sedimentary rocks, a statement as to the results of all the deep borings which have been reported, and predictions as to the probable depths and area of flow of the deeper-seated waters in all portions of the State. The water resources for shallow wells are not considered except in areas where such waters afford flows.

The investigation of underground waters is a branch of geology known as hydrology. In order to ascertain the underground conditions, it is necessary to map the surface distribution of the geologic formations, to measure their thickness, and to determine their structure. The character of the various sediments has to be examined to ascertain their porosity, and in many places their chemical nature has to be investigated in its bearing on the composition of the contained water. The evidence of fossils must be utilized to aid in establishing the identity of the various formations from place to place. Accordingly a hydrologic investigation of any area requires a detailed geologic survey, especially of its sedimentary rocks.

Underground water is derived from rain and melted snow and passes underground in porous materials such as sandstone, sand, and gravel. Some of it is absorbed directly by such materials, but much water passes underground by the sinking of streams in crossing the upturned edges of sandstones and other porous rocks. Along the slopes of the Black Hills many of the streams lose a large portion of their volume in crossing the porous strata. Much of the water thus absorbed seeps slowly through the rocks as their dip carries them to lower levels. The water is kept underground by a thick mass of relatively impervious shale overlying the sandstones, and when the sandstones are penetrated by wells in the lower lands artesian flows are obtained.

GEOGRAPHY AND TOPOGRAPHY.

South Dakota lies entirely within the Great Plains province, which comprises that part of the continental slope extending from the foot of the Rocky Mountains eastward to the valley of the Mississippi and merging into the prairies on the north and the low plains adjoining the Gulf coast and the Mississippi embayment on the south. The plains present wide areas of tabular surfaces, traversed by the broad, shallow valleys of large rivers and more or less deeply cut by the narrower valleys of the lateral drainage. Smooth surfaces and eastward-sloping rolling plains are the characteristic features, but in portions of the province the landscape is diversified by buttes, extended escarpments, and local areas of badlands.

The Great Plains province as a whole descends to the east about 10 feet in each mile, its altitude ranging from about 6,000 feet at the base of the Rocky Mountains to about 1,000 feet near Mississippi River. The altitudes and rates of slope vary considerably in different districts, particularly along the middle course of Missouri River, where the general level has been greatly reduced. South Dakota presents great extremes of altitude and variety of topography. Its lowest point, Bigstone Lake, is less than a thousand (967) feet above the sea, while the altitude of Harney Peak is 7,240 feet.

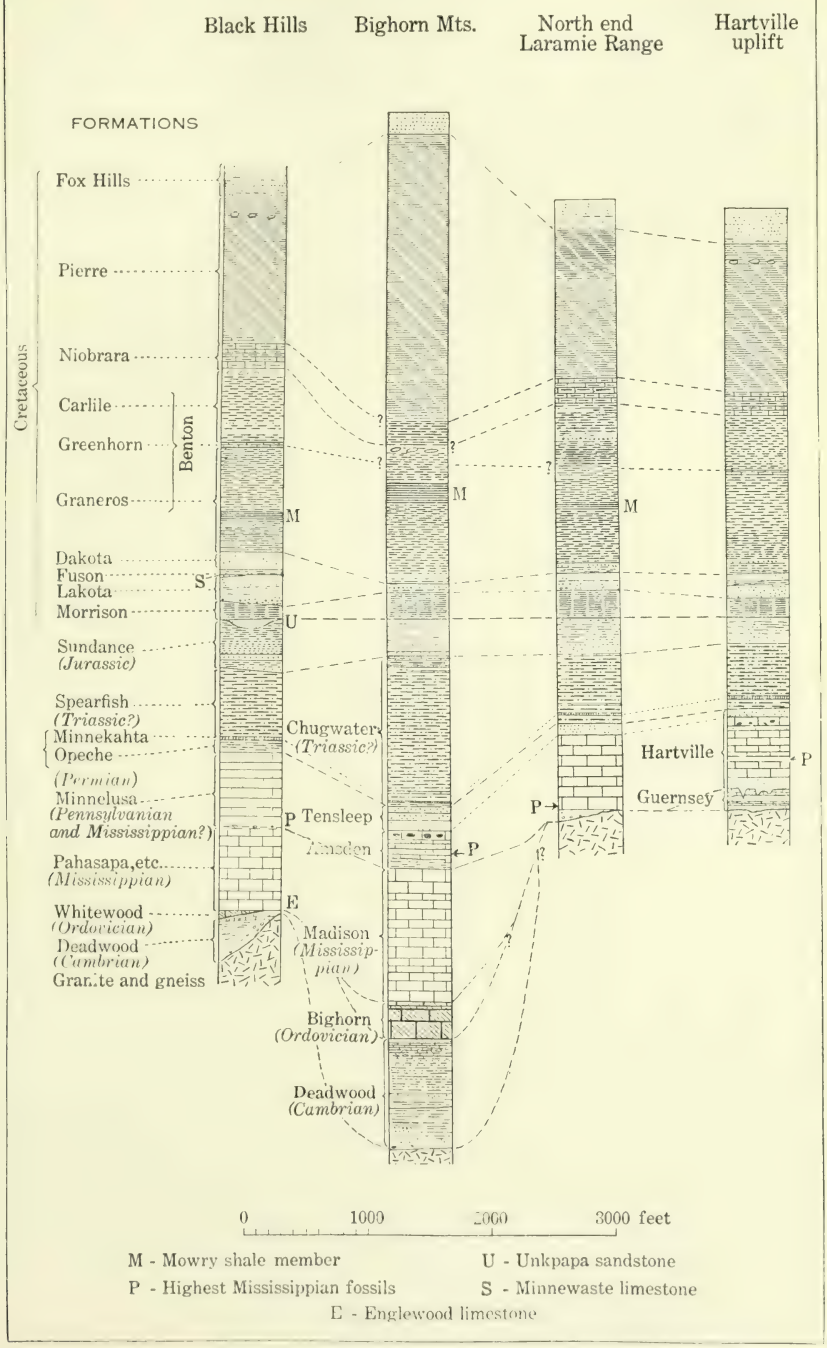
The principal drainage of South Dakota is carried by the Missouri and its tributaries. The main stream crosses near the middle of the State in a general southeasterly direction, receiving from the west the waters of Grand, Owl, Cheyenne, and White rivers, and from the east numerous smaller streams. At Yankton it is joined by James River, which also crosses the State from north to south, and in the southeast corner the Big Sioux enters it. The drainage of the northeast corner of the State is carried into the Mississippi by Minnesota River.

GEOLOGY OF THE BLACK HILLS REGION.[a]

GENERAL RELATIONS.

The Black Hills uplift is an irregular, dome-shaped anticline, embracing an oval area 125 miles long and 60 miles wide, with its longer dimension lying nearly northwest and southeast. It is situated in a wide area of nearly horizontal beds and has brought above the general level of the plains an area of pre-Cambrian crystalline rocks about

[a] For a detailed account of the geology of the Black Hills, see Darton, N. H., Geology and underground water resources of the central Great Plains: Prof. Paper U. S. Geol. Survey No. 32, 1905, 433 pp.; Darton, N. H., Preliminary description of the geology and water resources of the southern half of the Black Hills and adjoining regions in South Dakota and Wyoming: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 4, 1901, pp. 489–599; Jaggar, T. A., jr., Laccoliths of the Black Hills: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 3, 1901, pp. 163–303; Darton, N. H., and others, Oelrichs (No. 85), Newcastle (No. 107), Edgemont (No. 108), Sundance (No. 127), Aladdin (No. 128), Devils Tower (No. 150), and Belle Fourche (No. 165) folios: Geologic Atlas U. S., U. S. Geol. Survey, 1902–1909.



COLUMNAR SECTIONS OF BLACK HILLS, BIGHORN MOUNTAINS, NORTH END OF LARAMIE RANGE, AND HARTVILLE UPLIFT.

which there is upturned a nearly complete sequence of sedimentary formations, ranging in age from middle Cambrian to late Cretaceous, all dipping away from the central nucleus. There are also extensive overlaps of the Tertiary deposits which underlie much of the adjoining plains area. The region affords rare opportunity for the study of stratigraphic relations and variations. Many of the rocks are hard, and the streams flowing out of the central mountain area have cut canyons and gorges, in the walls of which the formations are extensively exhibited. The structure along the sides of the uplift is that of a monocline dipping toward the plains. The oldest sedimentary rocks constitute an escarpment facing the crystalline-rock area, and each stratum passes beneath a younger one in regular succession outward toward the margin of the uplift. Sections 2 and 3, Plate VI, show the general relations of the formations. The sedimentary members consist of a series of thick sheets of sandstone, limestone, and shale, all of which are essentially conformable in position, except the overlapping areas of the Tertiary deposits, which extend across the edges of the older formations. The stratigraphy presents many features of similarity to the succession of rocks in the Rocky Mountains of Colorado and of Wyoming, but it possesses numerous distinctive local features. The principal stratigraphic components are shown in the first column in Plate II; other columns on the same plate show their equivalency in other regions. The Silurian and Devonian and parts of the Cambrian, Ordovician, Triassic, Jurassic, and Tertiary are absent.

The following is a list of the formations which are exhibited in the uplift, with a generalized statement as to the ordinary thickness, characteristics, and age:

Generalized geologic section in the Black Hills region in South Dakota.

Age.	Formation.	Principal characters.	Thickness.
Quaternary			
Tertiary	White River group:		*Feet.*
	Brule clay		
	Chadron formation		
Cretaceous	Fox Hills sandstone	Sandstone with some shale	250–500
	Pierre shale	Dark-gray shale	1,200–1,400
	Niobrara formation	Chalk and calcareous shale	150–225
	Benton group:		
	Carlile shale	Gray shales with thin sandstones, limestones, and concretions.	500–800
	Greenhorn limestone	Impure slabby limestone	50
	Graneros shale	Dark shale with lenses of massive sandstone in its lower part at some places.	900–1,150
	Dakota sandstone	Massive buff sandstone	35–150
	Fuson formation	Very fine grained sandstone and massive shales, white to purple.	30–100
	Minnewaste limestone	Gray limestone	0–30
	Lakota sandstone	Massive buff sandstone, with some intercalated shale.	100–350
Cretaceous or Jurassic	Morrison shale	Massive shale, gray, greenish, and maroon.	0–150
Jurassic (?)	Unkpapa sandstone	Massive fine sandstone, white, purple, red, and buff.	0–250
Jurassic	Sundance formation	Dark-gray shales and buff sandstones.	60–300
Triassic (?)	Spearfish formation	Red sandy shales with gypsum beds	350–700

Generalized geologic section in the Black Hills region in South Dakota—Continued.

Age.	Formation.	Principal characters.	Thickness.
			Feet.
Carboniferous:			
Permian	Minnekahta limestone	Thin-bedded gray limestone	30–50
	Opeche formation	Red slabby sandstone and sandy shale.	90–130
Pennsylvanian to Mississippian(?).	Minnelusa sandstone	Sandstones, mainly buff and red, in greater part calcareous; some thin limestone included.	400–750
Mississippian	Pahasapa limestone	Massive gray limestone	100–700
	Englewood limestone	Pink slabby limestone	25–50
Ordovician	Whitewood limestone	Massive buff limestone	0–80
Cambrian	Deadwood sandstone	Red-brown sandstone and quartzite, locally conglomeratic, partly massive; some greenish-gray shale and limestone breccia.	4–450

CAMBRIAN SYSTEM.

DEADWOOD SANDSTONE.

The representative of the Cambrian, known as the Deadwood sandstone, appears to encircle the Black Hills entirely, but has been removed completely from the central area. Probably it did not originally cover the entire area of crystalline rocks in this region, a portion of these old rocks forming the surface during the greater part of Cambrian time and furnishing the material for the earlier sediments. The Deadwood strata lie unconformably across the upturned edges of the schists and granites, on a relatively smooth surface, with local shallow channels. The formation is thick in the northern hills, attaining a thickness of more than 400 feet in the Deadwood region (see Pl. III, *A*), but thins gradually to the south and especially to the southeast. In the region west of Fairburn exposures were found in which the formation is represented by only 4 feet of coarse sandstone lying upon pre-Cambrian schists. On Rapid Creek its thickness averages about 200 feet.

The materials of the formation are always predominantly sandy and the colors dark reddish brown or dirty buff. The basal member is ordinarily a hard, massive reddish-brown quartzite, with pebbly streaks. As the formation thickens this member can be seen to be overlain by thinner-bedded, softer sandstones, in some places interbedded with more or less shale. Portions of the basal beds of the Deadwood are conglomeratic, ranging from those with a sprinkling of quartz pebbles in the sandstone to a very coarse, heavy conglomerate made up of large rounded masses of crystalline rocks and vein quartz in a red-brown matrix.

Outcrops of the Deadwood sandstone vary greatly in prominence, but their extent in general is small. For many miles they lie in the slope below the high escarpments of the Pahasapa limestone, where the ledges are in places deeply buried under talus from the cliffs above. This is particularly the case on the west side of the uplift.

A. DEADWOOD SANDSTONE IN NORTHERN PART OF DEADWOOD, S. DAK.

Looking northwest.

B. LAKOTA SANDSTONE LYING UNCONFORMABLY ON UNKPAPA SANDSTONE, NORTH SIDE OF SHEPS CANYON, SOUTH DAKOTA.

On the east side, where the dip is steeper, the hard quartzitic basal member gives rise to knobs or long bare rocky slopes of considerable prominence. The many canyons cutting back into the western escarpment and those crossing the ridges on the east side of the uplift afford numerous excellent exposures.

In the region about Deadwood the formation comprises from 1 to 30 feet of basal conglomerate, overlain by 30 feet of sandstone, followed by 200 to 400 feet of gray shales, with layers of flaggy limestone, limestone conglomerate, and sandstone. Near the top is a very characteristic member of hard massive sandstone 5 to 22 feet thick, overlain by 20 to 45 feet of green shales. The limestone conglomerate consists of flat pebbles and flakes of limestone more or less thickly sprinkled with glauconite grains, a characteristic feature of the Cambrian of the Northwest. The formation contains middle Cambrian fossils.

ORDOVICIAN SYSTEM.

WHITEWOOD LIMESTONE.

The Whitewood limestone is conspicuous in the northern Black Hills, particularly about Deadwood, where it has a thickness of 80 feet and outcrops extensively in a number of canyons, a typical exposure appearing in Whitewood Canyon below Deadwood. It thins to the southeast and southwest and finally disappears. The rock is a massive tough limestone, of buff color with brownish spots or mottlings. It contains characteristic Ordovician fossils. In part of the area it is overlain by several feet of greenish shales which may possibly be Devonian, though no fossils have yet been found in them.

CARBONIFEROUS SYSTEM.

GENERAL OUTLINE.

In the Black Hills region the Carboniferous rocks comprise several formations apparently representing continuous deposition throughout the period. Many of the formations which compose the Carboniferous in the central United States are not recognized in the Black Hills, unless possibly in their broader faunal relations. There appear to be five separable formations—the thin Englewood limestone at the base, the massive gray Pahasapa limestone next above, the thick mass of Minnelusa sandy beds, the Opeche red beds, and the Minnekahta limestone; the last, at least, of Permian age. The Carboniferous lies directly on the Cambrian in the central and southern parts of the Black Hills, but to the north it is separated from the Cambrian by the Whitewood limestone and overlying green shales described above.

ENGLEWOOD LIMESTONE.

The Englewood formation consists of a series of thin-bedded pale pinkish-buff limestones, which appear to extend continuously around the Black Hills, everywhere immediately underlying the Pahasapa limestone. It averages 25 to 50 feet in thickness and presents numerous outcrops in the lower slopes of the limestone escarpment and in canyons. It merges rapidly into the overlying limestone, here and there with a few feet of impure buff limestone intervening. Generally it is sharply separated from the Deadwood sandstone or the Whitewood limestone, but only by an abrupt change in the nature of the materials. It is usually fossiliferous, containing numerous corals and a few shells, by which it is probably to be correlated with the Chouteau limestone of the Mississippi Valley.

PAHASAPA LIMESTONE.

The prominent Pahasapa limestone, formerly known as the "gray limestone," has an extensive outcrop area in the Black Hills uplift, constituting much of the high, wide plateau west of the central region of crystalline rocks, and being characteristically exhibited in the great lines of cliffs in the escarpment surrounding that region. It consists of a thick deposit of massive gray limestone, usually outcropping either in precipitous cliffs with many picturesque irregularities of form or in wide, flat surfaces. The formation does not present any noteworthy lithologic subdivisions, but in many places its upper part is siliceous and flinty and stained red to a greater or less extent from the overlying basal red shale of the Minnelusa.

The most extensive exposures of the Pahasapa limestone are in the great plateau west of Custer. Here the formation begins in a line of high cliffs, surmounting slopes consisting of crystalline schists and of the relatively thin sheets of Englewood limestone and Deadwood sandstone. In Pennington County the plateau has a width of 10 miles of continuous limestone outcrop, constituting the most elevated area in the Black Hills, except the small summit of Harney Peak. To the west the limestone passes beneath the Minnelusa sandstone, but it is exposed again in the arch of the steep anticline near the Wyoming-South Dakota line. East of the crystalline-rock area the limestone stands out on many conspicuous knobs or lies on the eastern slopes of ridges due to the quartzite of the Deadwood formation but does not attain the high altitude which it has farther west. The steeper dip to the east soon carries the formation below the surface in that direction, but it constitutes the walls of many of the canyons from Beaver Creek northward, notably the deep canyon of Spearfish Creek.

The thickness of the Pahasapa limestone in the central and southern Black Hills ranges from about 450 feet at the northwest to 225 feet at the east and southeast. All along the southeast side of the hills it remains at 225 feet, with slight local variations; then increases to 300 feet near Rapid, 350 feet on Elk Creek, and from 400 to 500 feet in the Deadwood region. In Spearfish Canyon 700 feet is reported by Jaggar. Fossils indicating Mississippian (lower Carboniferous) age occur sparingly throughout the formation.

MINNELUSA SANDSTONE.

The Minnelusa sandstone is next to the Pahasapa limestone in order of prominence among the Black Hills formations, extending around the uplift in a broad zone of conspicuous outcrops. The formation varies somewhat in components, but consists mainly of thick masses of buff and reddish sandstones, which are striking features in the walls of the many canyons by which the formation is traversed. The sandstones are mostly fine grained, massively bedded, and in their unweathered condition contain a considerable proportion of carbonate of lime. Thin sheets of limestone occur in places and, less commonly, sandy shales of red or gray color. Some layers are cherty. Although the formation probably was deposited at the same time as the "Coal Measures," which contain extensive beds of coal in the Mississippi Valley, it is barren of coal in the Black Hills, except in the local occurrence of very thin layers of impure coal in gray shales. The formation is thickest on the west side, where it is fully 600 feet thick. It thins gradually to the south and east, being about 420 feet thick west of Hot Springs and less than 400 feet thick on Spring Creek.

Although the Minnelusa sandstone has wide areas of exposure, it does not give rise to very marked topographic features, generally occupying elevated slopes surmounted by low hills and ridges due to its harder layers. Its inner boundary is usually not marked by an escarpment such as is seen at the inner margin of the Pahasapa limestone, and there is no noticeable topographic break in passing from one formation to the other. On slopes of the two formations the soil becomes sandy on the Minnelusa beds. In the many canyons which are cut through the formation the Pahasapa limestone is usually exposed beneath it without presenting any change of features except in color. The lower members of the Minnelusa are generally buff slabby sandstones, in many places having a thickness of 100 feet and a thin persistent bed of red shale.

Breccias, which occur in the middle beds, are a distinctive feature throughout the southern Black Hills. The brecciated material is usually somewhat more calcareous than the matrix, but it is all of

local origin. In the region west of Hermosa and thence northward the Minnelusa consists of a thick mass of coffee-colored sandstone at the top (see Pl. IV, *A*), reddish-buff sandstone with some thin interbedded limestone layers next below, and a basal member of gray sandstone.

The age of the formation has not been satisfactorily ascertained, for fossils are rare. A few impressions found in the upper beds west of Hot Springs appeared to be forms which indicate Pennsylvanian (upper Carboniferous) age for these beds. Mississippian (lower Carboniferous) forms have been found in concretions in the red shale at the base of the formation.

OPECHE FORMATION.

The series of red beds lying between the Minnelusa sandstone and the Minnekahta limestone extends continuously around the Black Hills. It is called the Opeche formation. Its exposures are almost invariably confined to the slopes below the escarpments of Minnekahta limestone. In thickness it averages slightly less than 100 feet. The materials are soft red sandstone, mainly thin bedded and containing variable amounts of clay admixture. At the top of the formation, for the first few feet below the Minnekahta limestone, there are shales which are invariably of deep-purple color. The basal beds of the formation are usually red sandstones, the beds varying in thickness from 4 to 15 inches.

On Spring, Battle, and French creeks the formation averages about 100 feet in thickness; in Beaver Canyon it attains its maximum thickness of 150 feet; on Cold Brook, 4 miles northwest of Hot Springs, it is 115 feet thick, with purple clay at the top, 50 feet of red sandy clay below, and 60 feet of red sandstone at the bottom, in beds 1 to 4 feet thick with red-clay partings; farther down Cold Brook, at a point 1½ miles from Hot Springs, a thickness of 135 feet is exhibited. Along the southwest side of the Black Hills the thickness averages from 90 to 100 feet, and on the northern slopes it is about 75 feet.

The age of the formation has not been definitely determined, for so far it has yielded no fossils. From the facts that the overlying Minnekahta limestone is of Permian age and that the deposition of red beds in some other regions began in Permian time, the formation is provisionally assigned to that series.

MINNEKAHTA LIMESTONE.

The Minnekahta limestone, long known as the "Purple limestone," is a prominent formation in the Black Hills region. Though thin, averaging less than 50 feet in thickness, it is hard and covers moderately extensive areas on the outer slopes of the Minnelusa sandstone.

A. TOP SANDSTONE OF MINNELUSA FORMATION, BEAR BUTTE CANYON, WEST OF STURGIS, S. DAK.

An important water-bearing horizon. (Photograph by T. A. Jaggar, jr.)

B. MINNEKAHTA LIMESTONE, WILDCAT GULCH, WEST OF HERMOSA, S. DAK.

Looking west across Red Valley.

The prominence of the Minnekahta limestone outcrops is due largely to the fact that the overlying formation is soft red shale, which has been deeply eroded, leaving the underlying limestone bare on slopes up which the red shale originally extended. As the underlying Opeche formation is also soft, the limestone nearly everywhere Presents an escarpment, and the many canyons which are cut through it have vertical limestone walls. (See Pl. IV, *B*.)

The formation is uniform in character throughout, being a thin-bedded light-colored limestone containing magnesia and more or less clay. Its bedding is a characteristic feature, although the thin layers are so cemented together that the outcropping ledges present a massive appearance. On weathering, however, it breaks into slabs usually 2 to 3 inches thick. The general appearance of the formation is slightly pinkish, with a tinge of purple, from which the term "Purple limestone" originated. The Minnekahta limestone contains some fossils which are believed to be Permian, in the sense in which that term is used in the Mississippi Valley.

TRIASSIC (?) SYSTEM.

SPEARFISH FORMATION.

The Spearfish formation is the conspicuous series of gypsiferous red beds encircling the Black Hills and in most places giving rise to the wide Red Valley. This valley is treeless and usually presents wide areas of bare red slopes and red buttes, with numerous outcrops of gypsum.

The formation consists of 350 to 695 feet of red sandy shale, with intercalated beds of gypsum in places 30 feet thick. The bright red of the shale and the snowy whiteness of the gypsum are striking features. Were it not for the beds of gypsum the formation would present no noticeable features of stratigraphy. The sedimentary material is almost entirely a red shale containing varying amounts of sand admixture, and is generally thin bedded. The gypsum occurs in beds at various horizons, some of the larger beds extending continuously over wide areas. There is also throughout the formation more or less gypsum of secondary deposition in very small veins.

The continuity of the outcrops of the red beds is considerably broken in the region west of Fairburn and Hermosa by overlaps of the Tertiary formations, which in some places completely fill the Red Valley. The width of the outcrop is from 1 to 3 miles, attaining its maximum in the region west of Buffalo Gap and in the broad belt extending from a point east of Minnekahta station nearly to the north end of Elk Mountain. Owing to the local steep dip of the formation, the outcrop is very narrow for 5 miles north from Cascade Springs.

The thickness of the Spearfish formation can seldom be determined with any degree of accuracy, owing to the softness of its materials and the numerous variations in its dip. In the deep well at Fort Meade the formation is 695 feet thick. Along the east side of the Black Hills it appears to be between 350 and 400 feet thick, so far as can be estimated from very indefinite dip observations. In this region the principal bed of gypsum occurs considerably below the center of the formation. West of Hermosa this gypsum bed has a thickness of about 15 feet, but toward the south, in the region west of Fairburn, it thins out and may at some points be absent. West of Buffalo Gap the gypsum deposits increase in thickness and attain their maximum prominence at Hot Springs, where the principal beds have a thickness of 33½ feet, with a 10-foot parting of red shale between them. In the wide part of Red Valley, extending southward from Hot Springs to Sheps Canyon, gypsum beds are a conspicuous feature, but they gradually diminish in thickness in that direction.

At Cascade Springs and thence northward on the west side of the anticline the dips are very steep and the outcrop of the Spearfish formation becomes so narrow that the Red Valley is only a few rods in width from the springs northward nearly to the railroad. Here a relatively accurate measurement was made of the beds from the steep slopes of the Minnekahta limestone to the basal sandstone beds of the Sundance formation. At the base of the Spearfish formation there are 150 feet of red sandy shales, then a bed of gypsum, in places 20 feet in thickness, overlain by 250 feet of red sandy shales with a few thin layers of gypsum, the formation here having a total thickness of 420 feet. Near Spearfish and Sturgis thick beds of gypsum occur near the top of the formation and a thinner bed is included about 120 feet above the base.

Throughout the Black Hills the formation is distinctly separated from the underlying Minnekahta limestone and the overlying shales or red sandstone of the Sundance formation. It has been regarded as Triassic in age, because it lies unconformably beneath marine Jurassic deposits and is underlain by the Minnekahta limestone, which is thought to be of Permian age. No determinable fossils have yet been discovered in the formation.

JURASSIC SYSTEM.

SUNDANCE FORMATION.

The outcrop of the Sundance formation extends continuously around the Black Hills uplift, appearing mainly along the outer slope of the Red Valley, or the lower, inner slopes of the hogback range. It carries abundant marine fossils throughout. The formation comprises from 225 to 350 feet of shales and sandstones, in a series which

varies but little in sequence in different portions of the region. The succession includes 50 to 60 feet of lower dark shale, 30 feet of massive buff ripple-marked sandstone, 30 feet of reddish sandy shale, and at the top 100 to 200 feet of green shale with thin fossiliferous limestone layers. Some local variation is presented, especially in the occurrence of massive red or buff basal sandstone which in many places attains a thickness of 25 feet. The fossils are of later Jurassic age.

UNKPAPA SANDSTONE.

The Unkpapa sandstone, the next overlying formation, is everywhere clearly separable both from the Sundance formation below and the Morrison shale or the Lakota sandstone above. It is a very massive fine-grained sandstone, varying in color from white to purple and buff. Its greatest development is in the foothill ridges or hogback east of Hot Springs. Its first outcrops to the south are observed about Cascade Springs, and it extends continuously from that region past Hot Springs, all along the east side of the Black Hills to Belle Fourche River. North of Buffalo Gap its thickness diminishes to less than 50 feet in most places, but north of Rapid it increases locally to 150 feet. It is thickest in Sheps Canyon, southeast of Hot Springs, where 225 feet was measured.

Some of the exposures east of Hot Springs are very striking in their colorings of brilliant pink, purple, and pure white. Near Buffalo Gap the rock has been quarried to some extent for building stone. Portions of the rock are beautifully banded with various colors, in part along the stratification planes, but in places diagonal to them. In the quarry west of Buffalo Gap these banded beds exhibit minute faulting in a most instructive manner, affording fine illustrations of block-fault phenomena. Contacts with the overlying buff Lakota sandstone are exposed at many points, and are marked by considerable unconformity due to erosion. One of them is shown in Plate III, *B*.

CRETACEOUS SYSTEM.

MORRISON SHALE.

The Morrison shale outcrop extends along the upper, inner slopes of the hogback range. It is absent in the southeastern portion of the uplift, from the vicinity of Hermosa to a point southwest of Hot Springs. Elsewhere the formation is generally from 100 to 150 feet thick and lies between the Unkpapa sandstone and the Lakota sandstone. The formation is mainly composed of "joint clay" or massive shale, somewhat darker and more fissile to the east than to the north and west. The predominating color is a very pale greenish gray, merging into chocolate and maroon. Thin beds of fine-grained

white or light-gray sandstone and some thin local layers of impure limestone are included. A few fresh-water shells were observed, and there is an almost general occurrence of dinosaur bones. The latter are classed in the Jurassic by some paleontologists, but others regard them as early Cretaceous.

LAKOTA SANDSTONE.

The Lakota formation, which consists mainly of sandstone, gives rise to the crest and upper slopes of the hogback ranges that form the outer encircling rim of the Black Hills. Its sandstones are hard, coarse-grained, cross-bedded, and massive, with partings of shale of no great thickness. Local deposits of coal occur in its base about Cambria, on Hay Creek, and east of Edgemont. In the central and southern Black Hills the thickness is usually from 200 to 300 feet, with local variations; to the north it averages about 100 feet. The Lakota lies on the Morrison shale except in the region from Hermosa to a point beyond Hot Springs, where it overlaps unconformably onto the Unkpapa sandstone. A typical exposure of this unconformity is represented in Plate III, *B*.

Although the Lakota sandstone presents the predominant features above described, there are numerous local variations in the thickness of the beds and in the occurrence of intercalated fine-grained members. In the canyon of Fall River, where the formation has a thickness varying from 225 to 250 feet, the beds of sandstone are very massive and are separated by greenish-gray shales 15 to 20 feet thick at several horizons. The uppermost member, a dull-yellow sandstone, is immediately overlain by the Minnewaste limestone in the region east of Hot Springs. The lower beds are conglomeratic at most localities.

Except petrified wood, which is abundant, fossils are rarely found in the Lakota sandstone. A few bones of a stegosaur were obtained near Buffalo Gap and remains of isopods, *Estheria*, fish, and crocodile were found 3 miles north of Piedmont. Plants of Lower Cretaceous age occur east of Hot Springs and in the Hay Creek region, and pine needles are abundant in some of the coaly layers. Cycads are found in places, notably in the slopes southwest of Minnekahta and near Blackhawk.

MINNEWASTE LIMESTONE.

The Minnewaste limestone overlies the Lakota sandstone from the vicinity of Cascade Springs northward to Buffalo Gap. For the greater part of its course it has a thickness of only 25 feet, but is conspicuous on the hogback ranges east of Hot Springs, extending far up the slopes on some of the higher divides. One of the most extensive exposures is at the falls of Cheyenne River, which are due

to this formation, the water falling over a ledge of it about 20 feet high. Widespread outcrops may be seen in the anticline 2 miles east of Hot Springs, where the strata dip steeply to the west. It thins out rapidly north of Buffalo Gap and appears to be entirely absent in the canyon of Fuson Creek. It is thin at Cascade Springs, and disappears a short distance to the west. An extended search has failed to detect any fossils in it, but it is of Lower Cretaceous age, as it lies below the Fuson formation. The rock is a nearly pure, light-gray limestone, presenting uniform character throughout.

FUSON FORMATION.

The Fuson formation consists of a series of fine-grained deposits lying between the Dakota and the Lakota sandstones and encircling the Black Hills. Its thickness averages about 65 feet, but varies considerably and is greatest in the northern hills. Its material consists of a mixture of clay and fine sand, as a rule massively bedded. Some beds of coarser sandstone are locally included, but most portions are nearly pure shale. The predominant color is white or gray, but in many places buff, purple, and maroon tints are conspicuous.

As the formation is relatively soft compared with adjoining sandstones, it usually gives rise to a depression between a low crest of Dakota sandstone on the one hand and the higher summits of the Lakota sandstone on the other. Locally it is covered by talus from the sandstone cliffs above. One of the most extensive exposures is at the falls of Cheyenne River, where the section is as follows:

Section of Fuson formation at falls of Cheyenne River, south of Hot Springs.

Dakota sandstone.	Feet.
Dark sandy shale	4
Soft gray slabby sandstone; plants	6
Compact white mudstone	8
Dark-green clay	1
Dark-gray compact mudstone	25
Very compact white mudstone	2½
Gray mudstone	6
Harder white mudstone	9
Purplish shale	1
White fine-grained sandstone	5–12
Purple shale	6–8
Light-buff massive sandstone	25
Dark-buff coarser sandstone, much honeycombed by weathering	25

Outcrops of the formation are considerably obscured by talus along the canyon of Fall River, but there are extensive exposures in the side canyons, notably in one on the steep side of the anticline 2 miles due east of Hot Springs, where much of the material is bright purple and strongly resembles a shale that has been subjected to heat.

Fuson Canyon affords some striking exposures of a portion of the formation in cliffs capped by Dakota sandstone. The uppermost bed is a moderately hard sandstone underlain by 10 feet of purplish-gray shales, 10 feet of white mudstone, and 20 feet of bright-purple shale. On Dry Creek the formation is represented by 50 feet of white massive shale. On Squaw Creek the Lakota sandstone is overlain by about 50 feet of buff and purple shale, grading upward to the Dakota sandstone through several feet of shale and thin sandstone. Northwest of Hermosa shales of bright color prevail, much of the material being purple. Near Rapid it is 100 feet thick, and near Sturgis 65 feet. Farther north it varies from 65 to 100 feet. On the south and north sides of the hills the formation is at many places mixed with considerable sand and sandstone. In the Hay Creek region it has yielded large numbers of fossil plants of Lower Cretaceous age.

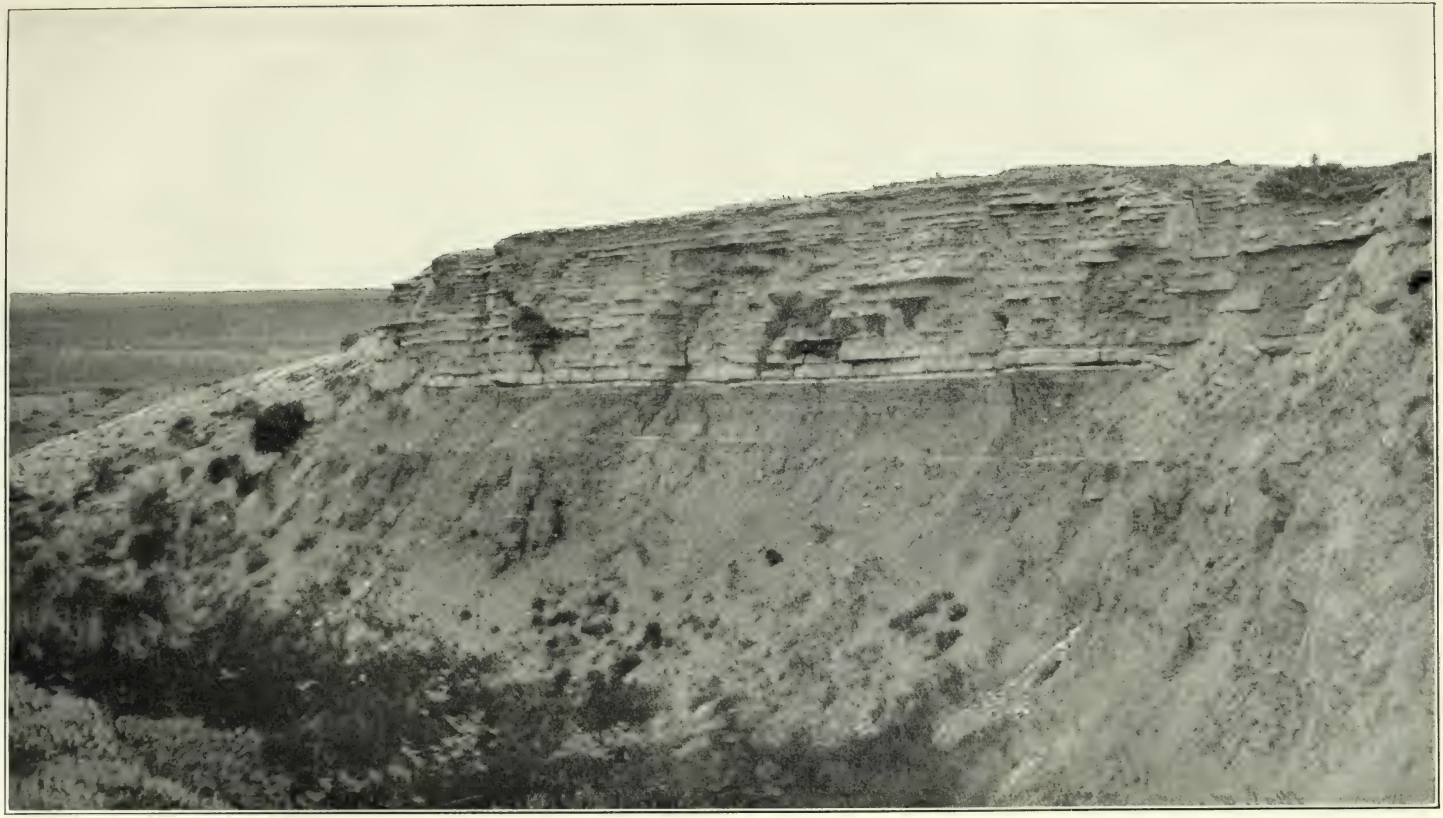
DAKOTA SANDSTONE.

The formation here designated the Dakota sandstone is the uppermost member of the series formerly designated "Dakota sandstone" in the Black Hills region. It extends continuously around the uplift, but being rarely more than 100 feet thick it constitutes only a small part of the hogback range. Nevertheless it is conspicuous, because the foothills to which it usually gives rise ascend steeply out of the adjoining valley or level plain underlain by the Graneros shale. It generally consists of gray sandstone, weathering brown. It is hard and massive below, but thinner bedded above. The fossil plants which have been obtained from it are impressions of dicotyledonous leaves, regarded as Upper Cretaceous in age.

BENTON GROUP.

Graneros shale.—The Graneros shale, which is the lowest formation of the Benton group, extends entirely around the Black Hills uplift, with a course marked by lowlands and valleys. It consists of dark fissile shale 900 to 1,150 feet thick, the maximum amount being north of Belle Fourche. From Edgemont to Sturgis the average amount is 900 feet.

In some areas the formation contains, toward its base, a thin layer of hard sandstone, which rises in a ridge of considerable prominence near Rapid, Hermosa, Newcastle, and Belle Fourche. It occurs locally, but apparently at the same horizon, from 150 to 300 feet above the Dakota sandstone. Its maximum thickness is about 30 feet. At Hermosa, where it is traceable from 4 to 5 miles, it is about 200 feet above the base of the formation and attains a thickness of 15 feet. At Rapid it is again conspicuous, but near Belle Fourche it is thin, soft, and in places absent.



GREENHORN LIMESTONE LYING ON GRANEROS SHALE, 4 MILES SOUTHWEST OF EDGEMONT, S. DAK.

Shows characteristic bedding of the Greenhorn, with shale intercalations, also abrupt change from the Graneros.

Next above this sandstone horizon is a series of hard gray shales known as the Mowry shale member. It is from 100 to 250 feet thick, and owing to its hardness gives rise to ridges of moderate prominence, many of which bear scattered pine trees. The shales of this member contain large numbers of fish scales and weather to a light silvery color, both characteristic features.

Greenhorn limestone.—One of the most prominent features in the plains immediately adjoining the Black Hills is a low but distinct escarpment, due to a hard limestone bed in the middle of the Benton group. It usually lies from 1 to 4 miles distant from the hogback ridge of the Dakota sandstone and presents its face toward the hills. It is thin but persistent, and is characterized by large numbers of impressions of *Inoceramus labiatus*, a fossil of scanty occurrence in the adjoining formations. It is believed to represent the Greenhorn limestone of Arkansas Valley.

The Greenhorn limestone contains a considerable amount of clay and fine sand. It appears to gain hardness on weathering, breaking into hard, thin pale-buff slabs covered with impressions of the distinctive fossil. Its thickness averages about 50 feet. At its base it is usually distinctly separated from the dark Graneros shale (see Pl. V), and in its upper portion it appears to grade into the Carlile shale through 6 or 8 feet of passage beds.

The most extensive exposures of the Greenhorn limestone are in the prominent escarpments west and northwest of Edgemont, which rise high above the slopes extending along either side of Cheyenne River. Owing to the low dip in this vicinity the limestone is spread out in plateaus extending back for some distance from the edge of the escarpment. In the region about Fairburn the formation is traversed by a syncline, which spreads it out into a bifurcated ridge south of the town. On the adjoining divides, notably in those between French Creek and Battle Creek and between Battle Creek and Spring Creek, the formation is buried beneath the overlapping White River deposits. It is well exposed in the banks of Battle Creek 1½ miles below Hermosa, where, in its only slightly weathered condition in the fresh stream cut, it is seen to be a hard calcareous light-gray shale filled with *Inocerami*. In the northern Black Hills it is a conspicuous feature about Belle Fourche, notably in a prominent butte known as Susie Peak.

Carlile shale.—The Carlile shale, which is the uppermost formation of the Benton group, consists of dark fissile shale with concretions, thin sandstones, and impure limestone layers, lying between the Greenhorn limestone and the Niobrara formation. Near the top of the formation numerous oval concretions occur, containing *Prionotropis, Prionocyclus,* and other fossils. The thickness ranges from

500 to slightly more than 750 feet, the larger amount being in the region north of Belle Fourche. Some typical sections are as follows:

Section of Carlile shale near Buffalo Gap.

Niobrara formation.	Feet.
Shales, with large buff concretions	150
Hard slabby sandstone	2
Gray shale	130
Thin coarse sandstone	4
Gray shale	75
Concretions in gray shale	2
Gray shale	40
Calcareous sandstone with *Ostrea*, etc	4
Shale and talus	180
Greenhorn limestone.	

Section of Carlile shale 1½ miles southeast of the falls of Cheyenne River.

Niobrara formation.	Feet.
Gray shale, with large buff concretions	50
Gray shale	70
Light-gray sandstone	4
Dark-gray shale, with thin sandy layers	160
Sandstone	2
Gray shales	150
Greenhorn limestone.	

NIOBRARA FORMATION.

The calcareous deposits of the Niobrara formation completely encircle the Black Hills, presenting distinctive features throughout, but to a less degree in the northeast than in the south. The material is a soft shaly limestone or impure chalk, containing greater or less admixture of clay and fine sand. In unweathered exposures it is generally light gray, but its weathered outcrops have a bright-yellow color which usually renders them conspicuous, although, owing to the softness of the materials, they give rise to few noticeable ridges. The thickness of the formation is about 225 feet in the central and southern Black Hills and 150 to 200 feet on the northern slopes. At many places thin hard layers are included, consisting of an aggregation of shells of *Ostrea congesta*, a fossil distinctive of the formation where it occurs in this manner.

PIERRE SHALE.

Many thousand square miles of the country adjoining the Black Hills are occupied by the Pierre shale. This formation is a thick mass of dark-colored shale, weathering light brown, and is relatively uniform in composition throughout. It gives rise to a dreary monotony of low rounded hills, sparsely covered with grass and not very

useful for agriculture. The thickness of the formation is 1,200 to 1,400 feet, so far as can be ascertained, but only at a few places can it be measured. Where it dips gently away from the hills it is almost impossible to measure the rate of the dip of the shale. Fortunately it has been found that the formation includes, at a horizon about 1,000 feet above its base, scattered lenses of limestone usually containing numerous shells of *Lucina occidentalis*. The greater number of these lenses occur at the definite horizon just mentioned, and in some places, where they occupy the surface over a wide area, they throw light on the attitude of the formation. It is evidence of this sort that provides a basis for the determinations of structure which afford an important part of the data for ascertaining the depth of the Dakota sandstone in the region adjoining the Black Hills.

The limestone concretions with *Lucina* vary in size from those of 2 or 3 cubic feet to masses 20 feet in diameter and 6 or 8 feet thick, usually of irregular lens shape. Owing to their hardness these lenses, when uncovered by erosion, give rise to low conical buttes resembling in form very squat tepees, and accordingly they have been designated "tepee buttes," a term used for similar occurrences in the Pierre shale of southeastern Colorado. They occur in large numbers in the vicinity of Oelrichs, east of Hermosa and Sturgis, and in the Willow Creek valley, varying in height from 10 to 150 feet above the surrounding slopes. Horizontally the lenses occur at irregular intervals, so that the buttes are scattered very erratically and some of them are separated by many miles.

Numerous concretions occur in the Pierre shale at various horizons and usually contain large numbers of distinctive fossils. *Baculites compressus*, *Inoceramus sagensis*, *Nautilus dekayi*, *Placenticeras placenta*, and *Heteroceras nebrascensis* are the more abundant, and *Lucina occidentalis* is found here and there. The most fossiliferous horizon is in the upper part of the formation. The concretions are generally small and of a calcareous nature, and they break into brown pyramidal fragments which are scattered more or less thickly all over the Pierre surfaces.

In the southern part of the Black Hills region there is, at the base of the formation, a very distinctive series of black, splintery, fissile shales, containing three beds of concretions. These shales have been included in the Pierre, though not yet found to contain distinctive fossils; they may be Niobrara. They are about 150 feet thick in the Edgemont-Oelrichs region, where they give rise to a steep slope, in places rising conspicuously above the lowlands eroded in the Niobrara chalk. The concretions exhibit a curious sequence. The lower ones are biscuit-shaped, hard, and siliceous; those in the layers next above are similar in shape and composition, but are traversed in every direction by deep cracks filled with calcite and locally scattered

crystals of barite; and those in the uppermost layers are large, lens-shaped, highly calcareous, and of a light-straw color, consisting mainly of well-developed cone-in-cone.

FOX HILLS SANDSTONE.

The sandstone of Fox Ridge extends westward to the margin of the Black Hills uplift, and outliers of it cap portions of the high divides between Cheyenne and Bad rivers and between Belle Fourche and Owl rivers.

TERTIARY SYSTEM.

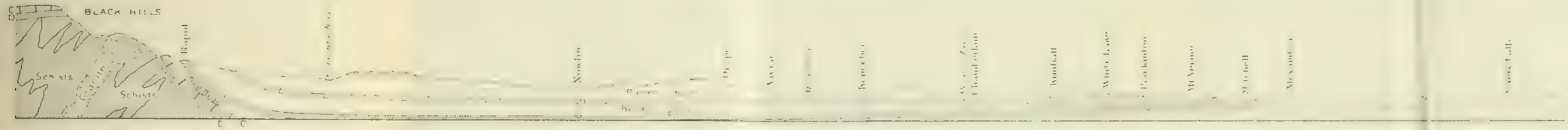
WHITE RIVER GROUP.

The well-known formations of the Big Badlands lying between Cheyenne and White rivers in western South Dakota and underlying Pine Ridge have been found to extend to the Black Hills and high up on their flanks in a portion of the region. About Fairburn and Hermosa wide areas of the highlands are occupied by the Chadron formation and the Brule clay, which give rise to numerous miniature badlands of considerable extent. The deposits comprise both fine-grained and coarse-grained materials, the latter marking the course of the more vigorous streams of the period. There are large areas of fuller's earth, sand, limestone, calcareous grit, and channels filled with conglomerate, in some places silicified and in others cemented by carbonate of lime.

The principal areas now remaining are on the high divides between Lame Johnny and Rapid creeks, but there are also extensive masses in the broad part of the Red Valley behind the hogback range, and narrow valleys filled with the deposits extend several miles back over the Carboniferous and Cambrian onto the Algonkian crystalline rocks. Some details of their distribution are shown on the geologic map (Pl. I). To the southwest there are scattered areas at a number of points between Edgemont and Pringle, notably on the Minnelusa sandstone west of Argyle, in the Red Valley north and west of Minnekahta, and on the Dakota sandstone not far north of Edgemont. South of Oelrichs there is a narrow basin which has been preserved in a syncline extending toward the Big Badlands.

The deposits of the White River group exhibit considerable diversity of composition. The principal material is a porous, crumbling clay, pale flesh color when dry, but light brown when damp. Some portions of it are pale green when dry and olive when wet. Much of it is fuller's earth, and differs from ordinary clay in being much less plastic. In the lower beds of the group it merges into sand on the one hand and into clay on the other. At many localities it is associated with or gives place to coarse materials occupying channels or broad sheets. In the vicinity of Hermosa the principal material is

SECTION 1



SECTION 2

SECTION 3

GEOLOGIC SECTIONS ACROSS SOUTH DAKOTA

BY N. H. DARTON

1908

coarse sandstone and conglomerate, mainly of dark-brown color, which mantles extensive plateaus. On the high level ridge north of Spring Creek there are coarse conglomerates, which extend entirely across the hogback range. About Fairburn and to the west there are long channels filled with conglomerate consisting of limestone pebbles and a calcareous matrix. These extend up several of the depressions through the hogback range, either displacing the fuller's earth deposits or being intercalated among them. The limestone pebbles appear to have been derived from Tertiary limestones, for they do not represent any of the Mesozoic or Paleozoic rocks of the hills. On the higher lands of the Red Valley, between Hermosa and Rockerville, there is an extensive deposit of nearly pure limestone, giving rise to a high plateau of considerable extent. The total thickness of the rock is about 30 feet at some places, the limestone being underlain by fuller's earth.

Limestones of various degrees of purity are abundantly intercalated in fuller's earth deposits which lie in depressions on the older rocks in the region west and southwest of Fairburn. Their most southerly occurrence is on the ridge a short distance northwest of the western entrance of Fuson Canyon and on the high divide just north of Lame Johnny Creek, a short distance west of the Chicago and Northwestern Railway. These limestones usually contain abundant fresh-water fossils, mainly gasteropods, at many places in great abundance.

There are extensive exposures of coarse materials of White River age in the railroad cuts through the divide south of Fairburn, where the materials are mainly cross-bedded coarse sands, with a large proportion of gravel, chiefly derived from the crystalline rocks of the hills. The thickness of the White River deposits on the flanks of the Black Hills varies from a thin remnant to 200 feet or more. In the divide just south of Lame Johnny Creek, in the Red Valley, at a point 10 miles southwest of Fairburn, more than 200 feet was measured, the deposit consisting mainly of pale flesh-colored sandy clay and fuller's earth.

The deposits of the White River group are usually divisible into two formations—the Chadron formation or so-called *Titanotherium* beds below and the Brule clay (including the so-called *Oreodon* beds) above. The Chadron formation consists of light-gray fuller's earth, and usually has at its base a bed of coarse gravel composed of rocks derived from the Black Hills. The Brule clay consists mostly of massively bedded sandy clay of pale flesh and drab colors.

All the White River beds have yielded fossil bones of various kinds which are typical of the Oligocene period.

The White River deposits southwest of Argyle consist mainly of fuller's earth of the Chadron formation. North and west of Minnekahta the material is a mixture of fine sand and clay. The outlier north-

west of Edgemont caps an area of Graneros shale high on the slope of the Dakota sandstone. It consists mainly of gray conglomeratic sandstone. In the vicinity of Lead and Garden small areas of White River strata have been found at an altitude of about 5,100 feet.

During White River time in the Black Hills and adjoining regions a considerable volume of volcanic ash was deposited. The epoch appears to have been one of volcanic activity in the region to the west, and the ashes were borne on the winds and dropped into the waters so as to be spread over a wide area of country adjoining the Black Hills. More or less volcanic ash occurs throughout the White River deposits as an admixture with the clay and sand. Accumulations of the pure material are found at various horizons.

GEOLOGY OF SOUTH-CENTRAL SOUTH DAKOTA.

GENERAL RELATIONS.

The portion of South Dakota lying south of Cheyenne River, between Missouri River and the Black Hills, is occupied by the Pierre shale and Tertiary deposits. On the divide at the head of Bad River there is an outlying area of Fox Hills sandstone. The Pierre shale extends along both sides of the Cheyenne River valley and southeastward to and beyond the middle and lower portions of the White River valley. It is also exposed along the Keyapaha. It consists of 1,000 feet or more of dark-gray shales, mostly soft and lying nearly horizontal. Missouri River cuts through them from the big bend southward, exposing the underlying Niobrara formation. The structure, as shown in sections 2 and 3, Plate VI, is a very gentle syncline, with the eastern side lower than the western. Wells at Capa and Nowlin penetrate the Pierre and underlying formations to the Dakota sandstone. This rock lies 1,500 feet below the surface at Capa and 1,770 feet below at Nowlin. It is overlain by about 1,000 feet of Benton and Niobrara, but the thickness of these beds was not determinable from the meager reports of the materials penetrated in boring. The 2,500-foot boring northeast of Rosebud entered the Pierre shale at 350 feet and passed through that formation and underlying beds to the Dakota sandstone, as shown in the record on page 132.

TERTIARY DEPOSITS.

The higher lands of south-central South Dakota are mantled by deposits of Oligocene and Miocene age. These reach a maximum thickness of about 600 feet near the head of South Fork of White River, but the amount is much less in most other portions of the area. The deposits lie on the Pierre shale except for local overlaps onto the Fox Hills sandstone at the head of Bad River and onto the Niobrara formation in the uplift south of Slim Buttes. It is probable that originally the entire region was covered by Tertiary deposits that extended

CHADRON AND BRULE FORMATIONS, BIG BADLANDS, SOUTH DAKOTA, NEAR HEAD OF CEDAR DRAW.

Looking east from Flour trail. Sheep Mountain in distance.

far to the northeast and west. This is indicated by the presence of outliers, notably those high on the slopes of the Black Hills.

The Tertiary consists of two principal subdivisions—the White River group (Oligocene) below and the Arikaree formation (Miocene) above—the distribution of which is shown on the geologic map (Pl. I). To the east and north the White River group thins and is overlapped by the Arikaree, apparently owing to progressively greater erosion of the former before the latter was deposited.

The White River group has been studied mainly in the Big Badlands between Cheyenne and White rivers, where three principal subdivisions were recognized—the lower one the Chadron formation or so-called *Titanotherium* beds (see Pl. VII), the middle the Brule clay or so-called *Oreodon* beds, and the upper a series of clays underlain by the *Protoceras* sandstone (see Pls. VIII, *A*, and IX, *A*), as it has been called. In the Brule clays there is at many places a marked sandstone horizon known as the *Metamynodon* sandstone. The upper limits of the Brule clay have not yet been settled. In 1900 it was discovered that in the higher slopes southeast of White River, in the western portion of the Pine Ridge Reservation, the *Protoceras* horizon is overlain by several hundred feet of clays and sandstones which were regarded as the top member of the White River group, for they are immediately overlain by the Arikaree formation in Pine Ridge. They are shown in Plate IX, *A*.

The upper beds in this area have been further described by W. D. Matthew,[a] who has discovered lower Miocene vertebrates in a member which he has named Rosebud. A. B. Reagan[b] has described the relations in the central part of the Rosebud Reservation.

GEOLOGY OF NORTHWESTERN SOUTH DAKOTA.

GENERAL OUTLINE.

Very little information is available on the geology of the northern portion of Butte County and of the Cheyenne River and Standing Rock Indian reservations. Several expeditions have passed across portions of the area and ascertained some of its geologic features. F. V. Hayden visited the eastern and southern parts of the region in 1854 and reported that it was occupied mainly by the Fox Hills and Laramie formations. In the lower lands adjoining Missouri and Cheyenne rivers the Pierre shale appears. In 1874 N. H. Winchell[c] crossed the western part of Butte County with the Ludlow expedition and recorded a wide area of "Laramie" to the north, succeeded by the Pierre and Benton as Belle Fourche River was approached. Outliers of Tertiary formations were noted on some of the high divides east of the Little Missouri.

[a] Bull. Am. Mus., vol. 23, pp. 169–219.

[b] Am. Geologist, vol. 36, 1905, pp. 229–243, map.

[c] Report of a reconnaissance of the Black Hills of Dakota by William Ludlow, U. S. A., Washington, 1875.

FORT UNION, LARAMIE (?), AND FOX HILLS FORMATIONS.

In 1884 Bailey Willis[a] examined the region extending from Grand River to Owl (Moreau) River, in the southwest corner of the present Standing Rock Indian Reservation. The rocks were classed as Laramie and Fox Hills formations, the latter grading downward into the upper portion of the Pierre shale. The uppermost formation, occupying the central divide between the two rivers, consists of light-yellow, gray, and dark-brown sandstones and sandy shale, with thin beds of lignite and iron nodules. On Cottonwood and Thunder creeks it was found to contain thick beds of fossils, including *Ostrea glabra* and *Melania insculpta*. Beds of lignite found at various localities are less than 3 feet thick, but there are numerous thin beds. There also occur numerous nodules of gray carbonate of iron. The strata are practically horizontal, but local dips of 1° to 3° are indicated in places, and the thickness of the rocks is estimated at about 700 feet. Next below the so-called Laramie are brownish sandstones which yielded *Tancredia americana* at the lower crossing of Flint Creek. Apparently the succession is regular, as no evidence of unconformity was noted. Next below are brownish sandstones without fossils, underlain by grayish-blue shale containing various Fox Hills fossils, which were collected on Owl River one-half mile below the mouth of Thunder Creek. These Fox Hills beds have an estimated thickness of 100 feet. They are underlain by dark-gray to blue-black tenacious clay, with local harder layers, and contain fossils regarded as transitional between the Pierre and the Fox Hills. These beds were examined on Grand River 15 miles east of the mouth of Flint Creek. The so-called Laramie beds appear first in isolated buttes on the divide 30 miles west of the Missouri, or near the head of Flint Creek.

In the summer of 1895 J. E. Todd made a reconnaissance of a portion of the region lying west of longitude 103° and his report[b] contains many important facts. He reported that the country north of South Fork of Owl River was occupied by Laramie and associated sandstones with detached high buttes capped by Tertiary deposits. One of the most extensive sections examined was at the south end of the North Cave Hills, where the following beds were measured:

Section at south end of North Cave Hills.

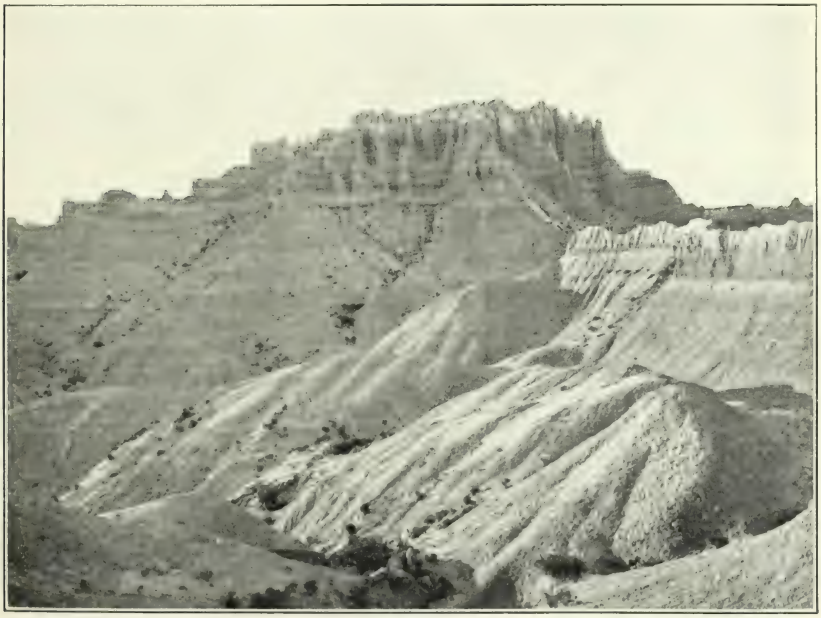
	Feet.
Yellow fine-grained quartzite or flint with casts of plant stems	2
Whitish marl with thin layers of limestone above	18
Purple massive sandstone	27
Gray and white plastic clay	12
Yellow massive sandstone	50
Soft yellow stratified sand	16

[a] Lignites of the Great Sioux Reservation: Bull. U. S. Geol. Survey, No. 21, 1885.

[b] First and second Biennial Repts., South Dakota Geol. Survey, 1893-96, Vermilion, 1898.

A. CENTRAL PORTION OF BIG BADLANDS: COTTONWOOD DRAW, SOUTH DAKOTA.

Shows middle members of White River group; Protoceras sandstone capping pillar at left.



B. SPUR AT SOUTH END OF SHEEP MOUNTAIN, BIG BADLANDS, SOUTH DAKOTA.

Brule clay and White River beds; volcanic ash at top.

	Feet.
Hard sandstone	1
Yellow sand	6
Gray sand	6
Dark plastic clay	70–75
Lignite	¾
Dark plastic clay	11
Good lignite	5
Dark-brown laminated clay	4
Yellow sand	2
Yellow laminated clay	10
Dark laminated clay	3
Loam	4
Shaly limestone	½
Loamy clay	5
Dark laminated clay	3
Lignite	½
Yellow loam	5
Laminated, ripple-marked concretionary limestone	1
Cream-colored laminated silt	8
Lignite	½
Gray sand	55–60
Laminated clay with lignite in the middle	1½
Light-colored sandy silt	6
Lignite	⅔
Cream-colored sandy silt, with some yellow calcareous sandstone concretions	4½
Dark laminated clay with 2-inch carbonaceous layer at top	4
Fairly pure lignite	5
Light cream-colored silt	6
Light-colored silt with flat concretions at the top	15
Dark laminated shale, about half of it impure lignite	4
Very light laminated shale	3
Black shale	¼
Light coarse sand, some small concretions	10
Plastic clay with three black bands of lignite	7
Black, very pure lignite	3½
Light clay	3
Break in section	30–35
Cream-colored silt, stratified	5
Thin shaly calcareous sandstone	1
Brown and gray clay silt	14
Gray clay	1
Lignite	½
Silt slope	9
Carbon streak with alkali	½
Light-gray clay	6
Obliquely laminated rusty sandstone	1
Yellow silt with some clay	8
Lignite	¼
Dark plastic clay	4
Lignite with large pieces of wood	2
Slope with alkali clay	10

The two upper beds are regarded as the White River formation.

It was found that the greatest development of sandstone is in the vicinity of Cave Hills, and that it thins toward the south and east. The beds composing the lignitic formation, however, are very variable in stratigraphy, and sections a few miles apart show great difference in components. The lignite beds occupy extensive areas, but they change rapidly in thickness and quality and are not all favorably located for mining. The most extensive deposit is the bed 5 to 7 feet thick lying from 150 to 200 feet below the top sandstone. This was traced eastward for 25 or 30 miles along the valley of North Fork of Grand River. Another thick bed occurs 100 to 125 feet lower, but the two are found in the same section only at the south end of the Cave Hills. Two thick beds occur at Florman's coal camp in or near sec. 23, T. 18 N., R. 7 E. At this place the following section is presented:

Section of coal measures in or near sec. 23, T. 18 N., R. 7. E.

	Feet.
Gray sand with thin layers of sandstone	10
Gray shale	3
Hard compact gray sandstone layer, very even and with few joints	10
Drab stratified clay, weathering yellow	3½
Good lignite	5½–6
Yellow sand with print of palm leaves	1
Light-drab stratified clay with leaf prints	2¾
Good shaly black lignite	9½
Laminated clay, yellow and drab, with many leaf impressions	18
Lignite	4½–8
Dark dirtlike clay	10
Shaly with pieces of lignite	12
Lignite	2
	96

The two coal beds in this section may correspond with those in the Cave Hills. The uppermost beds of the formation are at many places unconsolidated, and contain elongated concretions closely resembling saw logs in size, shape, and appearance. Some of these are from 50 to 100 feet long. The so-called Laramie includes all the strata in the Cave Hills, with the exception of the two upper members, all in the Slim Buttes below and including the rusty sandstone, all in the Deers Ears except an 8-foot cap of Tertiary conglomerate, and all of the East Short Pine Hill except the basal portion, which is supposed to be Pierre shale. No Fox Hills fossils were found, but if there is no unconformity between the Pierre and the so-called Laramie, doubtless sediments of Fox Hills age are represented.

Through recent work of A. G. Leonard[a] it is reasonably certain that the principal lignite-bearing beds of the northwestern part of the State are the same as those exposed in the valley of Little Mis-

[a] The North Dakota-Montana lignite area: Bull. U. S. Geol. Survey No. 285, 1906, pp. 316–330.

A. UPPER MEMBER OF WHITE RIVER GROUP, WOUNDED KNEE CREEK, SOUTH DAKOTA.

B. LIGNITIC BEDS AT SOUTH END OF NORTH CAVE HILL, BUTTE COUNTY, S. DAK.

Shows 5-foot seat of lignite near base. (Photograph by J. E. Todd.)

souri River in the vicinity of Medora, N. Dak. Knowlton and Peale believe that the latter are of Fort Union age, and the lignite-bearing beds of South Dakota are presumably of the same age.

POST-EOCENE.

Outliers of Tertiary deposits cap a number of high buttes on the divides between the Belle Fourche, Owl, Grand, and Little Missouri valleys. The most notable of these features are Castle Rock, Haystack, Slim, and Deers Ears buttes, and Cave and Short Pine hills. These hills rise several hundred feet from the rolling prairie of the lignite-bearing formation, which varies in altitude from about 3,000 to 3,500 feet. The deposits lie unconformably on that formation, and appear to belong largely to the White River group. In Slim Buttes and the Short Pine Hills they are capped by beds which are described by Todd as "Loup Fork," but which should probably be assigned to the Arikaree formation.

The White River beds have a thickness of about 100 feet in Slim Buttes, and consist mostly of gray clays, with thin layers of sandstone and sand. In places the sandstones thicken. Near the north gap in these buttes the beds are tilted at angles of 12° to 25° S. and SW. They are overlain by nearly horizontal Arikaree (?) beds. The White River deposits contain a large amount of flint, with irregular cavities, evidently due to plant stems, one-sixteenth inch to 4 inches in diameter, some of them with fossil wood still remaining. Thin deposits of gray to yellowish impure opal and thin veins and scattered masses of chalcedony also occur. Bones of Oligocene animals, including *Titanotherium*, *Oreodon*, and turtles, are reported. The overlying Arikaree (?) beds consist mostly of fine-grained white friable sandstone containing small globular concretions. Some portions are cemented by carbonate of lime and other portions with silica, the latter giving rise to a hard quartzite at a few localities. The thickness at the north end of Slim Buttes is 125 feet; in the Short Pine Hills it is about 200 feet. No fossils were observed. The following sections by Todd show the principal local features:

Section of White River group at southeast angle of Slim Buttes.

	Feet.
Clay, limestone fragments	9
Sandstone, coarse	2
Clay, whitish	38
Sandstone, light gray	4
Sand rock, fine clayey	50
Sandstone, coarse	9
Limestone, white, very hard, compact; lower part full of fossils of fresh-water shells	2–3
Clay, white	18
Clay, white, sandy	8
Sand with fragments of yellow flint with plant stems	1

The limestone evidently is similar to that which occurs near the base of the *Oreodon* beds in the Big Badlands and elsewhere.

Section of Tertiary deposits on northwest side of Slim Buttes, near Florman's coal camp.

	Feet.
Soil and soft white sandstone	20
Sandstone, hard layers	5
Clay, white, sandy, grading down into thin-bedded white sandstone	12
Sandstone, white, massive, with small globular concretions, some layers reddish and some shaly	60
Concretions, flat, reddish	1
Sandstone, white, stratified	6
Sandstone, soft, full of stalactite-like concretions	6
Sandstone, massive, argillaceous, weathering into globular masses and containing small globular concretions	15
Slope, mostly white soft sandstone	27
Gray clay, porous sandstone, fragments and several thin interrupted layers of sandstone obliquely bedded, usually dipping to the north	18
Rusty clays and sand, part white, part with thin layers of limonite	10

The beds in this section include both Arikaree (?) and White River, but the line between them was not indicated. In another section a few miles farther north the Arikaree beds at the top are 100 to 110 feet thick. They consist of white sandstones, with a 2½-foot bed of white chalky clay 30 feet above its bottom. Next below are clays of the White River formation, about 75 feet thick, containing a 12-foot bed of pure white sand 6 to 10 feet below the top. The top clay, which is of gray color, contains pieces of yellow flint, with casts of stems. The lower clays, 50 to 60 feet thick, are cream colored.

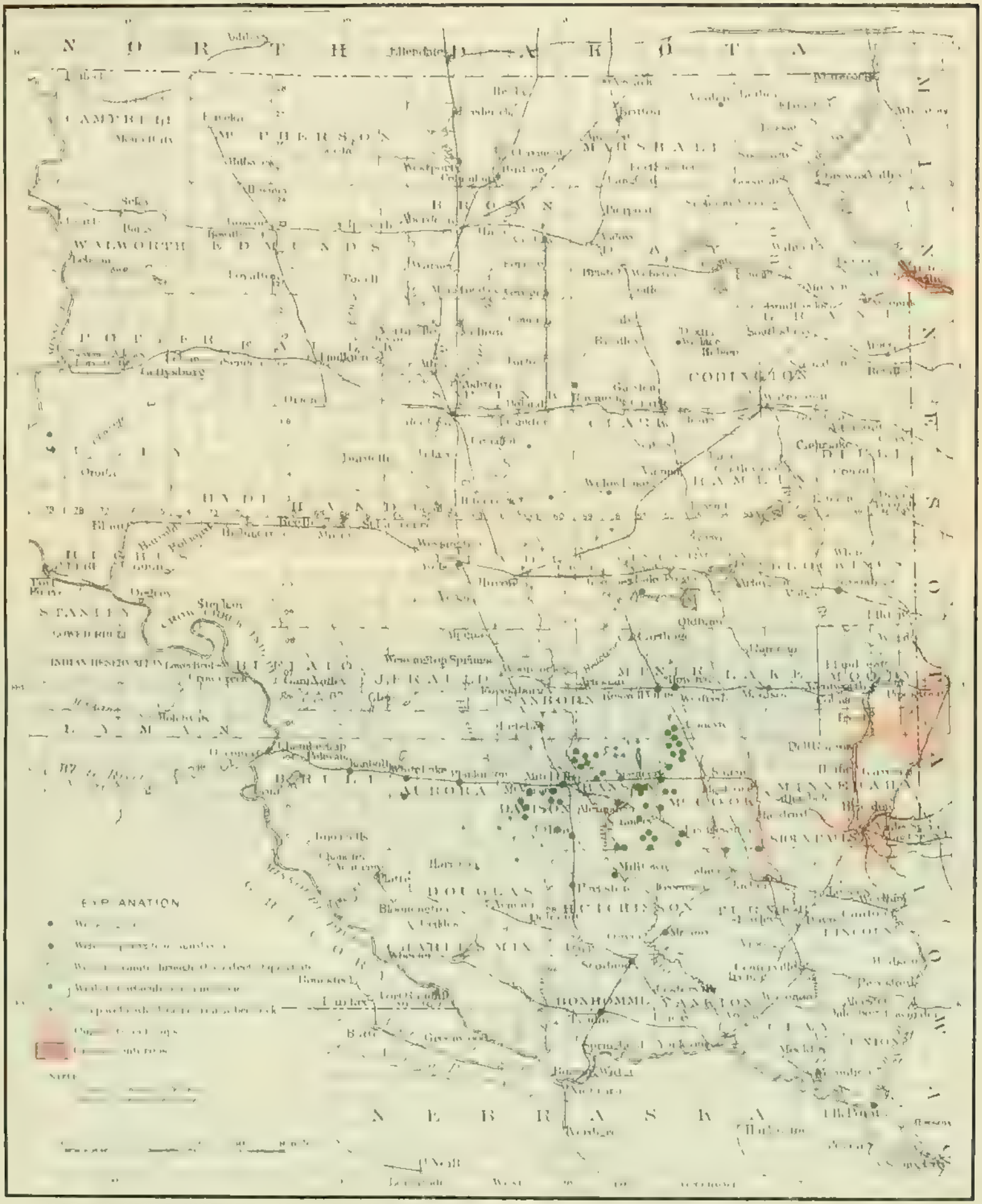
Castle Rock is capped by 110 feet of Tertiary deposits lying on Cretaceous clays. At the base are 30 feet of mostly fine, white, sandy, massive clay, merging downward into 5 feet of grayish-green sandy clay. The upper 75 feet is sandstone, mostly soft, but partly quartzitic, largely massive, but in places thin bedded and with a few pebbly layers. In some respects it resembles portions of the White River group of the Big Badlands, but at least its upper member may be an outlier of the Arikaree (?). No bones were found to throw light on this question.

GEOLOGY OF EASTERN SOUTH DAKOTA.[a]

GENERAL STRUCTURE.

The greater part of eastern South Dakota is heavily covered by glacial drift and outcrops of the underlying formations are rare. Fortunately, however, there are numerous deep wells, and from the

[a] The geology of part of this region is described in detail by J. E. Todd, in the Olivet (No. 96), Parker (No. 97), Mitchell (No. 99), Alexandria (No. 100), Huron (No. 113), De Smet (No. 114), and Aberdeen-Redfield (No. 164) folios: Geologic Atlas U. S., U. S. Geol. Survey, 1903–1909.



MAP SHOWING CONTOUR AND ALTITUDE OF "BED ROCK" SURFACE IN A PORTION OF SOUTH DAKOTA

BY N. H. DARTON, H. L. ROBINSON, AND M. HALL

1909.

records of these it has been possible to ascertain some of the broader features of structure and stratigraphy. Missouri River has cut a deep valley, which affords extensive exposures of the older formations, but the prominent feature for many miles in this valley is a long succession of high banks of Pierre shale. Below the great bend Niobrara chalk exposures begin, and they continue in the lower slopes as far as the mouth of James River. At this place the Benton group appears, and the Dakota sandstone finally outcrops in the extreme southeast corner of the State, near Sioux City, Iowa.

In the outcrops the rocks appear to lie horizontally, but when the relations are studied it is found that there are low dips in various directions. The principal feature is a general rise to the southeast, which, together with the diminishing height of the land, brings to view in that direction the lower formations in succession. There is also a low anticline with its axis extending westward through Mitchell toward Chamberlain, which brings the Niobrara and Benton formations and the Sioux quartzite to the surface over an area of considerable extent in the James River valley. This uplift is coincident with an old ridge of Sioux quartzite which was a shore during the deposition of the Dakota sandstone and, to a less extent, during Benton time, but apparently was almost if not entirely covered by the Niobrara waters. It was an outlying ridge completely separated from the main shore of granites and gneisses which rise in the Minnesota Valley and toward the northeast.

ARCHEAN AND ALGONKIAN ROCKS.

The pre-Cambrian crystalline rocks which underlie the Central Plains rise rapidly in the eastern part of South Dakota and finally reach the surface. One area of outcrop extends from the James River valley near Mitchell eastward to the vicinity of Pipestone, its appearance being due mainly to an anticlinal uplift; another is in the Minnesota Valley, where the rocks rise on the slope of the great uplift of the Minnesota area. The configuration of the "bed-rock" surface, as it is termed in eastern South Dakota, is shown in Plate X by contour lines determined partly by outcrops, but mainly from numerous wells which have either reached older rocks or failed to reach them, and thus, in a measure, have delimited their depth.

In addition to the general gradual rise of the "bed-rock" surface to the east, there is a conspicuously high underground ridge or promontory, which extends through Salem and Mitchell toward Chamberlain. This ridge, so buried beneath later sediments that it has no effect on the present topography, has steep slopes several hundred feet high, and would have considerable topographic prominence if the surrounding clays and sandstones were removed. The structure of the younger formations abutting against this underground ridge

indicates that although it is due partly to anticlinal uplift it was also a ridge of considerable height at the time of the deposition of the Dakota sandstone. The rock of this ridge, known as the Sioux quartzite throughout the area, outcrops extensively along Big Sioux River near Sioux Falls and at other points to the west and the northeast. This quartzite consists mainly of rounded or subangular sand grains cemented by silica and to a greater or less extent built into quartz crystals. It is usually very compact and intensely hard, so that steel of high temper is generally required for drilling it, though some portions are locally much softer. The predominating color is pale pink, but some of it is gray or buff. The bedding varies from slabby to massive. The thickness of the formation is not known, but a well at Sioux Falls 575 feet deep and one at Mitchell 225 feet deep were in typical quartzite throughout. In Hanson County the quartzite ridge rises steeply about 400 feet above an underground plain or valley, whose floor several of the wells have reached and found to be of granite, an occurrence which probably indicates that the present thickness of the quartzite rising to the south is less than 400 feet. As the surface of the quartzite was exposed to extensive erosion, especially during Pleistocene time, as shown by its being deeply scarred by glacial scratches, the original thickness doubtless was greater than it is at present.

To the northeast, in the vicinity of Pipestone, the Sioux quartzite is overlain by or merges into a very compact red clay known as catlinite, or pipestone, a material which has been long employed by the Indians for the manufacture of pipes and other articles. A few impressions resembling Cambrian fossils were reported from these deposits by N. H. Winchell, but it is believed that the Sioux quartzite as a whole is Algonkian, from its similarity to quartzites farther northeast which are known to underlie Cambrian rocks.

The Sioux quartzite is penetrated by dikes in the vicinity of The Dells, near Garretson, Minn., and an igneous mass has been found in well drillings in the southwest corner of Minnesota, and possibly also in sec. 25, T. 104 N., R. 58 E., in South Dakota. Outcrops of the Sioux quartzite occupy a considerable area at Sioux Falls and vicinity, and it rises in extensive and very picturesque walls, in places 50 feet high, in The Dells and on Split Rock Creek. The vertical cleavage which the rock presents in these two localities is a characteristic feature and is the principal factor in the palisadal structure that it exhibits. To the west the rock outcrops in most of the deeper valleys between Sioux Falls and Mitchell, notably on Vermilion River southeast of Parker, along East Fork of Vermilion River below Montrose, on West Fork of Vermilion River near Salem, on Black Earth Creek south of Salem, on Wolf Creek near Spencer and near Bridgewater, on Pierre Creek northeast and southeast of

Alexandria, on Johnson Creek and its branches north and east of Fulton, on Rock Creek northwest of Fulton, on James River west of Alexandria, at Rockport, and on Enemy Creek near its mouth.

Beyond the area of outcrop the quartzite has been reported from numerous wells of moderate depth in Minnehaha, Moody, Turner, Lincoln, McCook, Hanson, Hutchinson, and adjoining counties. It has been reported in deep wells in Aurora and Beadle counties, and at Scotland and Tyndall, in Bonhomme County.

The records of borings which are claimed to have reached bed rock do not always indicate the nature of the material, some of the drillers reporting "hard rock" or "very hard rock," which gives no clue to its nature. In a few wells samples have been obtained and submitted to persons qualified to determine their nature, but more commonly the record is based only on the judgment of the well drillers. Ordinarily these persons have been able to recognize the typical Sioux quartzite without much doubt, but their judgment as to other rocks is open to considerable question. It is asserted also that in several instances rocks collected on the prairie have been placed in the wells to be afterward churned up by the boring machine, either by some foolish person for mischief, or by the driller for the purpose of giving the impression that he had reached "bed rock" and could abandon further boring. In the following table are given all the data so far obtained regarding the occurrence of "bed rock" in the borings in eastern South Dakota and in the immediately adjoining portions of the adjacent States. This list does not include the many shallow wells which have reached the Sioux quartzite where it is near the surface in eastern Hanson County, central McCook County, and the counties along the eastern boundary of the State.

Wells bored to or into bed rock in South Dakota and parts of adjacent States.

Location.	Rock.	Depth.
		Feet.
Asylum near Jamestown, N. Dak.	Hard limestone	1,505–1,524
Hankinson, N. Dak.	Granite	400–426
Aberdeen	Quartzite	1,221–1,267
	Granite	1,267–1,300
Budlong well, sec. 18, T. 114, R. 62	Quartzite	922–995
	Granite	995–998½
Glidden well, ¼ mile west-northwest of Hitchcock	Quartzite	1,083–1,142
	Granite	1,142–1,150
Motley well, sec. 7, T. 115, R. 61	"Very hard rock"	1,050
Wolsey[a]	do	928–930
Huron	Quartzite on granite	1,070–1,139
Bohri well, near Raymond	do	1,198–1,200
Sec. 18, T. 102, R. 61	"Quartzite"	280
Sec. 25, T. 102, R. 62	do	280
Brookings	Quartzite	556
White Lake	Sioux quartzite	900
Pierre[b]	"Granite"	1,250–1,256
Henneau's well, sec. 34, T. 103, R. 60	Sioux quartzite	842
Sec. 17, T. 103, R. 61	"Quartzite"	312
Plankinton[a]	Sioux quartzite	745–830

[a] Nettleton, E. S., Artesian and underflow investigation: Rept. to Sec. Agr., pt. 2, 1892.
[b] Another well near by found no "bed rock" to a depth of 1,337 feet.

Wells bored to or into bed rock in South Dakota and parts of adjacent States—Continued.

Location.	Rock.	Depth.
		Feet.
Sec. 24, T. 104, R. 58	Granite	512–518
SW. ¼ sec. 25, T. 104, R. 58	Diabase	506
Sec. 36, T. 104, R. 58	Quartzite	480
Sec. 29, T. 104, R. 60	do	228
Sec. 13, T. 104, R. 57	"Hard rock"	204
NE. ¼ sec. 17, T. 104, R. 57	Gray granite	510
NW. ¼ sec. 19, T. 104, R. 57	do	557
Fulton	Quartzite	30
Ethan	"Hard rock"	320
Sec. 25, T. 104, R. 60	do	115
Mitchell	Quartzite	540–765
Doxheimer well, sec. 11, T. 103, R. 57	"Jasper"	153
Sec. 25, T. 103, R. 61	Dark-gray granite	500
Sec. 20, T. 102, R. 60	"Quartzite"	195
NW. ¼ sec. 32, T. 103, R. 61	Quartzite	288
Alexandria	Quartzite with sandstone and water below.	40
	In one well hard rock	490–496
Sec. 29 (?), T. 104, R. 59	Quartzite	100
Elm Springs	do	247–412
Spencer	"Jasper"	100
10 miles southeast of Salem	Quartzite	170
Salem	Sioux quartzite	220–247
West Point region	Quartzite	300
Humboldt region	do	140–153
Sioux Falls	do	0–575
County well, sec. 18, T. 100, R. 62	Granite	1,025
County well, sec. 26, T. 100, R. 64	Hard rock, "granite"	937
7 miles north of Parker	Quartzite	140
Parkston	Sioux quartzite	510–522
Do	do	542
Menno	do	410–417
Well in center of Turner County	"Very hard rock"	510–513 or 556–559
Secs. 28 and 23, T. 110, R. 57	Quartzite	1,056
Redfield, asylum	Granite	1,080–1,090
Kleinsasser well, sec. 4, T. 113, R. 60	Red granite	940–955
Madison	Black, schistose hornblendic rock.	1,300
Wallace	Granite	1,380
NW. ¼ sec. 4, T. 113, R. 58	do	990
7 miles southeast of Canastota	Quartzite	140
Fort Randall [a]	"Hard rock"	576–610
Scotland [a]	Quartzite	535–587
Tyndall [a]	do	735
Yankton	"Granite"	898–942
5 miles north of Alcester	"Hard rock"	480
Veblen, Marshall County	Granite	860
Vermilion, University well	Quartzite	630
Britton	Red and gray granite	1,030
Layson well, sec. 22, T. 94, R. 61 [a]	"Very hard rock"	1,074–1,075½
Elk Point	"Hard rock"	303
Do	do	367
Milbank [b]	Granite	280–303
Albee, Grant County	do	168
Whiterock, Roberts County	do	500
Brown Valley, Minn. [a]	Granite (?)	425–465
Canby, Minn	"Granite"	400
Moorhead, Minn. [c]	Granite	360–1,750
6 miles south-southwest of Marshall, Minn	do	505–505½
Ponca, Nebr. [a]	Sandy shale and green clay	420–455
	Limestone	455–498
Sioux City, Iowa [d]	Limestone, chalky at top	335–1,255
	Sand, marl, etc	1,255–1,320
	Limestone and sandstone	
	Quartzite (?)	1,510–1,525
	Granite or gneiss	1,525–2,071
NE. ¼ sec. 28, T. 115, R. 79	Granite (?)	1,780–1,781
SE. ¼ sec. 3, T. 115, R. 79	do	1,645–1,646

[a] Nettleton, E. S., Artesian and underflow investigation: Rept. to Sec. Agr., pt. 2, 1892.
[b] Winchell, N. H., Notes on some deep wells in Minnesota: Fourteenth Rept. Geol. and Nat. Hist. Survey Minnesota, 1888, p. 14.
[c] Winchell, N. H., Natural gas in Minnesota: Bull. Nat. Hist. Survey Minnesota No. 5, pp. 27–31.
[d] Todd, J. E., Notes on geology of north-northwest Iowa: Proc. Iowa Acad. Sci., 1891.

These data, in the main, satisfactorily agree with one another and with the general structure. A few indicate rather unexpected details of configuration of the "bed-rock" surface, but on the whole the apparent distribution of the various rocks and the underground contour of the surface on which the water-bearing Dakota sandstone lies are everywhere in reasonable accord. (See Pl. X.) The general form of all the larger features is indicated, at least approximately, by the record of more than one well.

It is undoubtedly the case that more complete data, or a different interpretation of certain well records, might suggest modification of the contours shown, but such modification would probably be in respect to minor details.

The high quartzite ridge extending underground nearly due east and west through Minnehaha, McCook, and Hanson counties, and prolonged with diminished height to White Lake and beyond, is perhaps the most noteworthy feature shown. Its extent and altitude are deduced very obviously from the records of a large number of borings which are fully in accord in nearly every respect. In several wells the Sioux quartzite, with its unmistakable texture and pink color, was penetrated for a number of feet, and between James River and Enemy Creek, near Mitchell and the Minnesota line, are numerous exposures of the rock in the depressions which cross this buried ridge. As previously stated, at Sioux Falls the typical Sioux quartzite was penetrated by a boring to a depth of 575 feet without reaching its base, and at a number of other points as far west as White Lake it has been penetrated to a considerable depth.

A sample of the material penetrated between 512 and 518 feet, from the boring in sec. 24, T. 104 N., R. 58 E., was found on examination to be a dark granite. This was at the base of the north side of the buried quartzite ridge above referred to, and would indicate that the quartzite is underlain by granite. In two county wells in the northern part of Douglas County granite was reported in a similar position on the opposite side of the quartzite ridge, but the identity of the rock is open to some question. The deep valley in the bed-rock surface lying north of the buried quartzite ridge is indicated by the fact that the Huron, Iroquois, Woonsocket, and Madison wells did not reach bed rock.

At Madison a black schistose hornblendic rock was found at a depth of 1,300 feet, or 372 feet above sea level. It is on this evidence that the deep bed-rock valley is shown to extend southward under Lake County. The evidence of the line of borings from Brookings to Wolsey indicates some interesting features of underground topography in the bed-rock surface. None of the borings give definite evidence as to the nature of the rock penetrated. In the De Smet well, it was at one time supposed that the quartzite had been reached

in a hard rock at a depth of 1,456 feet; but at 1,470 feet the drill passed out into soft sandstone, presumably of Dakota age, which carried water. As no bed rock was reported in the 800-foot boring at Arlington, the bed-rock surface evidently slopes down gradually from 1,160 feet above sea level at Brookings to less than 200 feet above sea level at Iroquois, where no bed rock was reached. At Huron the occurrence of bed rock at slightly less than 200 feet above sea level indicates the position of the deeper portion of the basin, for the bed-rock surface appears to rise steeply toward Wolsey. Nettleton is authority for the reported occurrence of the rock in the Wolsey well at an altitude of 420 feet above sea level, as he states in his "log" of this well that at 928 feet the boring entered very hard rock, into which it penetrated 2 feet. This would indicate the presence of a ridge terminated by steep slopes, on the west as shown by the deep wells around Miller and St. Lawrence, on the south, as indicated by wells north of Wessington Springs, and on the east, as indicated by the deep wells southwest and southeast of Huron, none of which reported bed rock.

The prolongation of this ridge to the north is fully borne out by the record of three wells north and northeast of Hitchcock. In two of these, the Budlong and Glidden wells, the quartzite was bored through and the underlying granite entered for a short distance. In the third well, at the ranch of Mr. Moxley, bed rock is reported at an altitude of 250 feet above sea level, but it was not penetrated and its nature was not stated. Borings from the Glidden and Budlong wells were examined, and there is no doubt as to the nature of both the quartzite and the granite, as indicated in the logs and stated in the table on page 35. The middle portion of the quartzite in the Budlong boring was not so distinctive in character as the upper and lower beds, for it appears to be of a somewhat softer material. The borings from the granite contained unmistakable feldspar fragments of jagged outline and in very fresh condition, together with some scales of mica and a large amount of quartz, mainly showing sharp edges. Some of the quartz grains were rounded, possibly by water action, but just as likely by the churning of the drill. It is also possible that some or all of these rounded grains were of sedimentary origin, but if so they were undoubtedly derived from the overlying quartzite. It should be borne in mind in making a judgment on borings of this character that more or less of the overlying material is detached by the drill in its descent and ascent below the bottom of the casing. As the process of drilling in so hard a rock as granite is relatively slow, there is much more chance for the admixture of material detached from above than in rapid boring through soft beds.

The precise course of this ridge, which passes south of Hitchcock and extends probably to Wolsey, and its relations to the adjacent

slopes of the bed-rock floor eastward are not definitely known, but the presence of bed rock in wells in T. 113 N., R. 58 and 60 E., the experience of the Bohri well, near Raymond, and the absence of bed rock in the 1,200-foot boring at Clark indicate approximately the features shown in Plate X. The Doland, Redfield, Ashton, Turton, Conde, Mellette, and Northville deep borings, which did not reach bed rock, indicate that it is not prolonged toward the north. The Bohri well penetrated supposed bed rock for 2 feet, but no report was given as to the nature of the rock except that it was very hard. The deepest boring at Aberdeen found the water-bearing beds and some underlying shales and sandstones underlain by 46 feet of quartzite lying on granite which was penetrated for 33 feet. This relation of the quartzite to the granite is in accord with the experience of the wells near Hitchcock. The position of bed rock in the Aberdeen well, in relation to that in the Hitchcock region, indicates a relatively gentle slope from the top of the Wolsey ridge to Aberdeen. To the east of Aberdeen there is but little evidence as to the nature and rate of the bed-rock slope, but the relations of the Groton, Andover, and other wells which did not reach it indicate that its rise is very gradual. This is further shown by the altitude of bed rock in wells at Britton and Veblen, to the northeast.

The boring at Milbank, in which the granite was penetrated for some distance, the surface outcrops of the formation in the Minnesota Valley below Ortonville, and the presence of granite at a depth of 168 feet at Albee all bear out the idea of regular slope. The Brown Valley well appears to have reached the granite on this slope and to have penetrated it for a short distance. The material is not stated to be granite by Winchell, but as part of the borings were "greenish micaceous kaolinic clay or shale," and "white, opaque, and wholly unwaterworn angular quartz grains," it seems exceedingly probable that the material represented granite in at least the lower 40 feet of the boring.

It is reported that the quartzite was penetrated in a number of wells in the southeast corner of South Dakota, including those at Parkston, Scotland, Tyndall, and Menno, and a well southwest of Parker. At Yankton the granite was reached at so low an altitude that a valley in the bed-rock surface is indicated. At Fort Randall the nature of the hard rock, which according to Nettleton was penetrated for 34 feet, is not stated, but presumably it was quartzite. The nature of the hard rock found in two borings at Elk Point is not known. The Ponca and Sioux City borings found Carboniferous limestone underlying the Dakota water-bearing beds, possibly with a thin intervening representative of some intermediate formation. The Sioux City boring passed through a great mass of the limestone, some limestone and sandstone, and 15 feet of a hard brown rock

which, according to Todd, may be the Sioux quartzite, and then penetrated for nearly 550 feet into hard gray granite. The borings at Parkston and Menno and southwest of Parker indicate that the buried quartzite ridge which is so prominent from the vicinity of Mitchell to Sioux Falls sinks rapidly to the south but at a less slope than to the north, and this slope is further delimited by the experience of borings near Parker and in central-western Turner County. The steep slope in the Canton region is indicated by the relation of the surface outcrops, the rapid increase of thickness of the Dakota and overlying Cretaceous sediments, and the records of one or two borings in the southern part of Lincoln County. To the south of the steep southern front of the buried quartzite ridge there appears to be a relatively gentle slope intersected by two valleys, one of which heads near Menno, as indicated by the failure to reach bed rock in a 747-foot well and by the relations of the wells in eastern Douglas County. The position of the bed rock at Pierre is uncertain owing to contradictory reports from two wells, one claiming to have penetrated granite at a depth of 1,250 to 1,256 feet, or at an altitude of about 190 feet above sea level, while another boring near by was sunk to a depth of 1,537 feet and found no bed rock.

The irregular contour of the bed-rock surface, as shown in Plate X, is no doubt due partly to subaerial erosion prior to the deposition of the Dakota sandstone. It has been suggested that the quartzite ridge which extends through Mitchell is a portion of the Dakota sandstone locally lithified, but the evidence of overlap and many other relations appear to indicate that this can not possibly be the case.

PALEOZOIC TO JURASSIC.

Although it is probable that the Paleozoic rocks extend for some distance eastward from the Black Hills, southward from Manitoba, and northward from Nebraska, they are absent in most of that part of South Dakota lying east of Missouri River. The deeper wells at Aberdeen and Pierre found materials apparently all of Cretaceous age lying directly on the old crystalline rocks. South and east of these localities the same conditions prevail, and on the underground ridge of the Mitchell region even the Dakota sandstone is absent in an area of considerable size. South of this ridge, as far as Yankton and apparently also at Elk Point, numerous wells have found the Dakota sandstone underlain by quartzite and granite without suggestion of intervening rocks. At Ponca, Nebr., however, the Dakota sandstone is underlain by a series of limestones and sandstones which undoubtedly represent the Carboniferous and possibly still older sedimentary rocks, and at Sioux City, Iowa, similar relations were found. These indicate that the Paleozoic rocks, especially the Carboniferous, which

are so extensively developed in Iowa and Nebraska, extend at least to the southeast corner of South Dakota.

The red beds and marine Jurassic sediments probably do not underlie eastern South Dakota. It is possible, however, that the formation there termed Dakota may include, locally, at the base the Morrison, Lakota, and Fuson formations of the Black Hills and of the Rocky Mountain region. There is, however, no direct evidence on the subject, since the rocks do not outcrop, and it is mentioned here merely as a suggestion.

CRETACEOUS SYSTEM.

DAKOTA SANDSTONE.

The Dakota sandstone underlies the greater part of eastern South Dakota, rising to the surface in the extreme southeast corner of the State. The predominant material is soft sandstone, moderately fine grained and porous for the most part, and of light-gray color. Intercalated beds of clay or shale, of greater or less extent, separate the sandstone layers. The sandstone lies directly on crystalline rocks—granite or quartzite—but is absent on the higher part of the underground quartzite ridge in the Mitchell region and to the east. Although it rises in approaching this quartzite ridge, mainly owing to anticlinal uplift, it does not arch over but appears to be terminated by a shore line, beyond which there is an overlap of the Benton.

The configuration of the base of the Dakota sandstone on "bed rock" is represented on Plate X and that of the upper surface on Plate XIV. It will be seen that the contour lines representing the upper surface show considerable difference in slope from that of the bed-rock surface, a difference indicating variations in thickness of the formation. This is an important condition as affecting water resources, but there is a great scarcity of precise data bearing on the subject. The formation thins rapidly on the slopes of the quartzite ridge in the Mitchell area, and apparently also about Kimball and Hitchcock, but in other portions of the region appears to average from 150 to 300 feet in thickness. No two sections show the same succession of beds having any constant thickness. The deepest well at Aberdeen penetrates the formation to the underlying "bed rock," indicating a thickness of 301 feet. In this well the formation lies between 920 and 1,221 feet and presents the following succession:

Section of Dakota sandstone in well at Aberdeen.

	Feet.
Dark-gray sandstone, water	15
Brownish and gray sandstone, pebbly in part, some pyrites and shale	142
Fine gray sandstone	23
Fine hard brown shaly sandstone	72
Fine white clay	15
Fine gray sand, no water	34
Quartzite.	

Another report gives 77 feet of clay as constituting the lower part of the 142-foot series and 37 feet of clay as the lower part of the 72-foot series.

In Spink County many of the deep wells penetrate the formation for 40 to 208 feet, traversing thick masses of sandstone with thin bodies of shale. In the Frankfort well the formation lies at 800 to 1,008 feet, with the following succession:

Partial section of Dakota sandstone in well at Frankfort.

	Feet.
Conglomerate, at 800 feet	3
Sandstone	122
Hard shale	20
Sandstone	40
Hard shale	15
Sandstone	8+

The Glidden and Budlong wells, near Hitchcock, penetrate to the granite of an underground ridge of the older rocks, on which the Dakota sandstone thins and changes character somewhat. The succession in the Glidden well is as follows, beginning at the first sandstone below a very thick mass of Benton shales:

Section of Dakota sandstone in Glidden well, three-fourths mile west-northwest of Hitchcock.

	Feet.
Sandstone, at 881 feet	6
Shale and limy conglomerate	30
White "limestone"	20
Yellow sandy shale	34
White sand, main flow	3
Shale and limestone	62
Coarse sand	10
White shale and limestone	38
Quartzite.	

This record was furnished by P. J. Stacy, the borer, whose identification of materials is exceptionally reliable. The section presents some features unusual for the Dakota sandstone. The Budlong well shows the following section:

Section of Dakota sandstone in Budlong well 5 miles northeast of Hitchcock.

	Feet.
Sandy shale, at 776 feet	10
Hard sandstone	3
Conglomerate	30
Sandstone, soft	5
Dark shale	10
Sandy shale	12
White shale	19
Conglomerate	25
Sandstone, dry	12
White shale	19
Quartzite.	

The Bohri well in Clark County, a short distance northeast of Raymond, entered water-bearing sandstone, supposed to be Dakota, at the depth of 1,005 feet and was bored to "hard rock," presumably quartzite or granite, at 1,200 feet. The following record, if accurate, shows a remarkably thick body of shale below the sandstone:

Section of Dakota (?) sandstone in Bohri well, near Raymond.

	Feet.
Sand rock and shale, at 1,005 feet	20
"Lime rock"	25
Sandstone	3
Shale	90
Green shale with rock layers	55
Hard rock ("quartzite"?).	

Two wells at Huron, in Beadle County, have bored through the Dakota sandstone into the underlying quartzite and granite. The following is the record in one of them:

Section of Dakota sandstone in city wells Nos. 3 and 4 at Huron.

	Feet.
Sandstone, with strong flow, at 740 feet	5
Sandy shale	50
Hard sandstone	12
Sandstone; much water	65
Gray limestone, Shale, Sandstone, thin, Shale	58
Sandstone	3
Black shale	125
Pebbly sand and water	9
Coarse sandstone on quartz rock or granite	30

At Wolsey, 12 miles west of Huron, is another well which is claimed to have gone to the base of the Dakota. The following strata are reported:

Section of Dakota sandstone in well at Wolsey.

	Feet.
Sandstone, with flow, at 880 feet	30
"Limestone" (?)	20
Sandstone	20
Hard shale	15
Sandstone	10
"Limestone" (?)	25

At De Smet, on the highlands 30 miles east of Huron, a deep boring passed through a thick series of sandstone with shale intercalations, probably comprising the greater part of the Dakota and including in its upper beds the lower portion of the Benton.

Partial section in lower part of boring at De Smet.

		Feet.
Benton (?)	Hard sandstone, at 840 feet	25
	Sandstone (?)	120
	Shale	200
Dakota	Sandstone	271
	Hard sandstone	14
	Sandstone	140

In Sanborn County many wells have reached the Dakota sandstone. The well at the mill in Woonsocket penetrated a solid mass of it from 697 to 775 feet, but had no need to go to the base. A well 2 miles southwest of Letcher reports Dakota sandstone from 400 to 863 feet without reaching the base; the material is mainly clay, including several sandstone layers with flowing water. In the Ashmore well, southwest of Artesian, the Dakota appears to have been entered at a depth of 626 feet; its upper members are 6 feet of sandstone and 67 feet of shale, lying on sandstone, which was penetrated for 2 feet.

In Davison County the thicknesses are variable and diminish rapidly until the formation feathers out in an irregular area on the higher slopes of the underground ridge of Sioux quartzite, south and southwest of Mitchell. At Mitchell the Dakota sandstone appears to extend from a depth of 445 feet to the quartzite at 540 feet, comprising 39 feet of sandstone above and 11 feet of sandstone at the base, separated by 50 feet of shale. In the Smith & Davison well, 4 miles southwest of Mitchell, in a valley in the buried quartzite ridge, the formation is represented by 40 feet of sandstone and 10 feet of shale resting on quartzite, the top of which lies at a depth of 475 feet. At Ethan only 8 feet of sandstone, which may be Benton, occur on the quartzite. In the Lowrie well, northwest of Ethan, the formation appears to be 92 feet thick, lying on quartzite at a depth of 477 feet and consisting of a top member of sandstone about 30 feet thick and a lower series of shales. The formation thickens rapidly to the west and south, and in the J. K. Johnson well, 3 miles due north of Mount Vernon, the section, which does not reach the underlying bed rock, is as follows:

Partial section of Dakota sandstone north of Mount Vernon.

	Feet.
Sandstone, at 350 feet	70
Shale	50
Sandstone	36
Shale	95
Sandstone	44+

In Aurora County several wells penetrate the formation for 100 feet or more and find alternations of sandstone and shale. The well at Plankinton is said to have reached granite at 756 feet; the overlying Dakota, beginning at a depth of 538 feet, appears to comprise

218 feet of beds consisting largely of shale, with several thin sandstone bodies. At White Lake beds at a depth of 790 to 850 feet are reported as sandstone and shales lying on supposed granite. The Storla well, in the northeast corner of the county, reports beds apparently Dakota at a depth of 457 to 760 feet, as follows:

Partial section of Dakota (?) sandstone in Storla well, Aurora County.

	Feet.
Sandstone, at 457 feet	13
Shale	60
Sandstone	5
Shale	30
Sandstone	10
Shale	45
Sandstone	10
Shale	110
Sandstone	20+

In the Dougan well, 4 miles northeast of the Storla well, there were 23 feet of sandstone on 60 feet of shale, lying on sandstone. In the Bartow well, 3 miles northeast of Plankinton, the following beds are reported:

Partial section of Dakota sandstone in Bartow well, near Plankinton.

	Feet.
Sandstone, at 455 to 516 feet	61
Shale	104
Sandstone	Few.
Shale, etc	133
Sandstone	2+

In the Resley well, 4 miles southeast of Plankinton, the section is as follows:

Partial section of Dakota sandstone in Resley well, near Plankinton.

	Feet.
Sandstone, at 477 feet	12
Shale	116
Sandstone	5
(?)	24
Shale	45
Sandstone	39+

The formation is absent in the central and southern portions of Hanson County, but in its northern and northeastern parts has been penetrated by several deep wells and found to consist of 20 to 53 feet of sandstone lying on granite or quartzite. Apparently it thickens rapidly to the north in the western part of Miner County and in the southeastern part of Sanborn County.

In the northern portion of Hutchinson County, the formation thins out against the Sioux quartzite slopes, but is more than 100 feet thick to the south and the west. At Parkston it appears to have been

entered at a depth of 460 feet and found to end at "very hard rock," probably quartzite, at 542 feet. Its upper member is a 12-foot bed of sandstone, below which there are alternations of shales and sandy shales. A later boring gives 35 feet of sandstone on 20 feet of shale, lying on the quartzite at a depth of 520 feet. At Tripp 95 feet of sandstone are reported, extending from 729 to 824 feet in depth without reaching the bottom of the formation. In the Morris well, 5 miles north by west of Tripp, the formation was penetrated at 505 to 595 feet without reaching its bottom. It consisted of sandstone with muddy layers below a 7-foot shale bed, with a very hard sandstone cap 28 feet thick at the top.

But little is known of the thickness or character of the formation in the southwest half of Turner County, which it underlies. A well at Hurley appears to have reached its top at a depth of 400 feet; 3 miles west of that town a well 513 feet deep is reported to have passed through 93 feet of sandstone, with some pyrites and shale, and to have penetrated the underlying quartzite for 3 feet.

In Clay County the Dakota sandstone is reached by many wells, but none of them appear to penetrate it for more than 30 to 40 feet.

In Yankton County several wells have been drilled 150 to 200 feet into the formation. At Yankton one of the later borings has reached the underlying granite at a depth of 898 feet; in the Asylum well, 3 miles to the north, it is reported that the Sioux quartzite was reached at 825 feet. These data indicate a thickness of 415 to nearly 500 feet for the Dakota sandstone. The following record is given of the lower beds in the city deep well:

Section of Dakota sandstone in well at Yankton.[a]

		Feet.
Benton(?)	Sand rock, at 353 feet	20
	Shale	37
Hard rock		3
Sand with water		15
Shale		17
Sand with water		30
Hard rock		4
Shale		27
Flint		2
Coal		1
Shale		26
Hard sandstone		10
Sand with water		15
Shale		20
Sandstone		29
Fine sand		196
Clay		2
Sand		62
Greenish clay		7
Tough green rock.		

[a] Todd, J. E., Bull. South Dakota Geol. Survey No. 2, 1898, p. 101.

In Bonhomme County the Dakota sandstone varies considerably in thickness and presents the usual variability in character. At Springfield it appears to have been penetrated from 440 to 592 feet without reaching its bottom, the upper 90 feet consisting of sandstone and shales and the lower 62 feet of a solid mass of very permeable sandstone containing a great volume of water. In the Layson well, on the highlands northwest of Springfield, the formation was entered at a depth of 810 feet and supposed bed rock was found at 1,075½ feet; the beds consist of an upper member of 230 feet of sandstone with very little water and a lower series of sand, gravel, and sandstone lying on 38 feet of black mud at the base of the formation. The well at Scotland reached a depth of 680 feet, passing about 80 feet into the Sioux quartzite and obtaining only a moderate supply of water from the Dakota sandstone. The following record begins below a thick body of shales and a succession of limestone and shales and thin sandy layers which continues to a depth of 476 feet.

Partial section in well at Scotland.

	Feet.
Sandstone and shale streaks with flowing water	34
Red shale and hard sandstone	8
Gray sandstone with flowing water	40
Pyrites	1
Pinkish sandstone	31
Limy pinkish sandstone on soft Sioux quartzite	12

Some of the wells in Charles Mix County have penetrated the Dakota sandstone for greater or less distances without reaching its bottom. The usual irregular alternations of standstones and clays are reported, the sandstones locally thickening to 70 feet, as in the Lake Andes well. In the Hammer well, west of Castalia, a hard rock with pyrites, supposed to be the top of the Dakota, is reported from 725 to 755 feet. Next below are 30 feet of shales and 181 feet of water-bearing sandstone.

As most of the Brule County wells obtain abundant water supplies from the upper part of the Dakota sandstone they do not penetrate it very deeply. At Chamberlain the formation has been explored for over 100 feet; some drillers report it solely as sandstone, but others state that heavy masses of shale separate the sandstone layers. At Kimball sandstone was entered at 900 feet and as the upper beds did not yield as much water as was desired the well was continued to a depth of more than 1,200 feet, all in sandstone.

In Buffalo, Jerauld, Hand, and Hyde counties the Dakota sandstone has been drilled for water, but only its upper beds have been penetrated. In Faulk County many wells pass into the formation for 150 to 200 feet and find sandstone predominating, with shale alternations in some areas. No well has reached the bottom of the forma-

tion. At Gettysburg, in Potter County, the formation appears to extend from a depth of 1,780 to 2,130 feet and to be overlain by 310 feet of sandy shales with pyrites. The formation consists of sandstone at the top, 20 feet of sandy shale, 40 feet of sandstone, and 90 feet of alternating sandstones and shales to the bottom of the well.

At Pierre, in Hughes County, two deep wells have recently been completed which throw light on the stratigraphy of the Dakota sandstone, one of them, it is claimed, having reached bed rock. The top of the formation lies 1,130 feet below the surface.

Section of Dakota sandstone in wells at Pierre.

	Feet.
Sandstone, yellowish, at 1,130 feet	10
Sandstone and limestone	35
Sandstone, yellowish	10
Shale, limestone, and sandstone	30
White sand, soft	30
White shale and limestone	25
Granite (supposed) at 1,260 feet	260

In another well 900 feet west of this one a depth of 1,537 feet was attained without finding granite. Below 1,325 feet the boring went through 125 feet of gray shale and 87 feet of highly carbonaceous shales with some pyrites and lignite. From these two borings a thickness of more than 600 feet is indicated, but the lowermost formation may be older than Dakota.

In the well on the Rosebud Reservation the Dakota sandstone appears to have been entered at a depth of 2,240 feet and the boring continued in it to 2,500 feet, a thickness of 260 feet, without reaching bottom. All the rock was fine-grained sandstone with a few thin layers of shale and some pyrites.

The Dakota sandstone contains abundant plant and molluscan remains in its outcrops along Missouri River near Sioux City, Iowa, and in Nebraska and Kansas. An extensive flora is represented, constituting the typical Dakota flora of Upper Cretaceous age. The Mollusca are fresh-water forms, which occur in considerable variety, but are not very distinctive as to age. According to Todd, *Goniobasis*, a fresh-water mollusk, was found in considerable numbers at a depth of 785 feet in wells near Esmond. This fossil is typical of the formation in the outcrop region to the south. Todd also reports that plant impressions were found in a well near Hitchcock.

BENTON GROUP.

Nearly all of eastern South Dakota is underlain by the Carlile, Greenhorn, and Graneros formations, constituting the Benton group, the exceptions being on the higher portions of the underground ridge of Sioux quartzite extending eastward from Hanson County and along

Minnesota River. The group has a thickness of several hundred feet and consists mainly of dark-colored shales or hard clays, with thin beds of sandstone, parted near its middle by the very characteristic Greenhorn limestone, presenting a succession of beds similar to those in the Black Hills, but greatly decreased in thickness. Over a considerable area a notable bed of water-bearing sandstone occurs at or near the top of the Carlile shale, being either immediately overlain by the Niobrara chalkstone or separated from it by a small amount of black shale.

The Benton group outcrops extensively along the south bank of Missouri River below the mouth of the James River and in the valley of the Big Sioux below Canton. One of its most typical exposures is on the south side of the Missouri, opposite Vermilion, where the thickness is about 250 feet and where there is in the lower medial portion a very characteristic bed of slabby limestone 30 to 40 feet thick—the Greenhorn limestone of the Black Hills and Rocky Mountain region—filled with the typical fossil, *Inoceramus labiatus*. The basal beds are dark shales, similar to the Graneros shale of the region farther west, 50 to 90 feet thick. The upper beds are Carlile shale, about 160 feet thick, containing several thin sandstone layers and zones of concretions. The group is also exposed at intervals in the bluffs along the east side of the Big Sioux and southward to Sioux City, Iowa, where its included limestone has been mistaken for the Niobrara, possibly on account of a small amount of chalk that is associated with it.

The group also appears to be near the surface under the drift in the Minnesota Valley, as indicated by the occurrence of *Prionotropis woolgari* in shallow wells about Milbank. Other outcrops, due to uplift and erosion, appear along James River and some of the tributary valleys in Davison, Hanson, and Hutchinson counties. The most extensive of these exposures are along Twelvemile, Enemy, and Firesteel creeks and on James River in the vicinity of the quartzite. The principal material in these outcrops is a buff or brown massive sandstone, exposed for a thickness of 15 to 20 feet at the greatest. The grain is coarse; there is more or less cross-bedding; and in many places small pebbles are included—all being features very suggestive of the Dakota. Heretofore, in fact, this sandstone has been regarded as a part of the Dakota. In well borings near by, however, it is found that it is underlain by several hundred feet of shales of typical Benton character, in some places containing distinctive marine fossils and underlain by typical Dakota sandstone. It contains some fragments of wood and a few leaves, and undoubtedly is the product of shallow waters, which continued even as late as the beginning of Niobrara time along the shore afforded by the ridge of Sioux quartzite. Shark's teeth are reported from the associated

shales, also indicating marine conditions. Benton shales, associated with this sandstone, are exposed at a number of points along Enemy, Twelvemile, and Firesteel creeks and James River.

The formations of the Benton group, as shown by the records of the wells, present considerable variation in local character and thickness. Apparently they thicken gradually to the north and the west, being thinnest in the area of outcrop in the southeast corner of the State. In the vicinity of the quartzite ridge, in Davison County and the counties to the east, they appear to thin out and disappear, overlapping the edges of the Dakota sandstone considerably. Probably, also, there are some small outlying areas under the drift on portions of the quartzite ridge.

In the northeastern portion of the State, unfortunately, the Niobrara formation is not clearly recognized, so that the limits of the Benton group can not everywhere be ascertained. In the wells at Aberdeen the group appears to be 400 feet thick, if certain limestones that are given in the records really belong to the Niobrara. On the same basis the group is 480 feet thick in the Andover wells. In Spink County the amount is somewhat less, but it appears to be 310 feet in the Cavanaugh well, near Hitchcock, and 380 feet in the Glidden well, measured downward from the bed of sandstone which appears to be the one that characterizes the summit of the Carlile shale in other portions of the region.

In Beadle and Kingsbury counties the thickness of the Benton group appears to vary from 400 to 500 feet, probably increasing to the west, although the limits of the formations are not defined in that region. In eastern Jerauld County the Benton group is 540 feet thick in the Feistner well, 510 feet in the Beug well, and 471 feet in the Schmidt well.

In central and southern Sanborn County, where the group lies nearer the surface, the thicknesses vary greatly, diminishing rapidly toward the south. In Davison County the relations are clearly ascertained by numerous well borings, in which the thicknesses are found to vary mostly from 200 to 300 feet, and the upper sandstone continues to be a characteristic feature. This sandstone thickens and thins locally, ranging from 20 to 85 feet in the southwestern part of the county, and is usually directly overlain by the Niobrara chalkstone, although in portions of the area there is an intervening mass of shale, which locally attains a thickness of 50 feet.

In the northern part of Hanson County, where the formations of the Benton group vary in thickness from 250 to 300 feet, the upper sandstone is a conspicuous feature. In the vicinity of Ethan, Davison County, the formations are 190 to 200 feet thick, and at Ethan 182 feet thick from the chalk above to a basal sandstone 8 feet thick, which may be Dakota, lying on the quartzite. The stratigraphy

varies considerably in this region, there being at various horizons thin layers of sandstone, some of which yield a flow of water under moderate pressure.

In Miner County the formations of the Benton group have been penetrated at Carthage, where the chalk was found to be underlain by 30 feet of the upper sandstone of the Carlile, and this by 250 feet of shale, with considerable pyrite in layers, lying on typical Dakota sandstone.

In Hutchinson County the formations of the Benton group present their characteristic features, but thin considerably on the slopes of the buried quartzite ridge in the northern portion of the county. At Tripp a thickness of 400 feet is reported, comprising 100 feet of sandstone immediately underlying the chalk; at Scotland a thickness of 285 feet, with 25 feet of the top sandstone; and at Vodnany a thickness of 305 feet, with the top sandstone very thin. In Turner County the formations of the Benton group are 265 feet thick in two wells near Hurley, consisting entirely of dark shale. In Aurora County they average about 300 feet thick and usually have from 20 to 70 feet of sandstone at the summit, immediately overlain by the Niobrara chalkstone. In Charles Mix County the Lake Andes well has the following record in formations of the Benton group:

Section of Benton group in well at Lake Andes, S. Dak.

	Feet.
Black shale, at 237 feet	30
Yellow sandy shale	39
Dark shale	145
Blue shale, with limestone streaks	50
Shelly lime rock	25
Blue shale (on Dakota sandstone)	70

In Brule County the Benton group appears to be from 400 to 500 feet thick and includes sandstone layers at some localities. At the Crow Creek well in Buffalo County it is 350 feet thick, with the usual thin bed of sandstone at the top just below the Niobrara chalk. In Bonhomme County the group varies considerably in thickness, being about 300 feet thick in the Springfield well and 420 feet in the Layson well, on the highlands northwest of Springfield. In Douglas County a thickness of 350 feet is indicated, including a top sandstone of general occurrence underlying the chalk and a great mass of shales below, with a few thin layers of limestone. These thin layers of limestone are mentioned in many of the well records in the southern townships, and probably represent the characteristic Greenhorn limestone horizon. To the south this limestone includes some chalky deposits like those of the Niobrara, but of no great thickness. The top sandstone is from 38 to 60 feet thick in wells about Armour. In the wells about Yankton the group appears to

be not over 300 feet thick, and apparently it thins considerably toward the east to its outcrop area in Clay County.

In Grant County, as recently ascertained by Todd, the upper portion of the Benton group—the Carlile shale—appears to come to the surface beneath the drift, for in shallow wells about Milbank numerous *Prionotropis woolgari* occur. The outcrops of sandstone that are reported by the Minnesota Geological Survey in Lyon County and northwest along the eastern slope of the coteau appear to be the upper sandstone of the Carlile formation. One exposure 2 miles northwest of Taunton is a thin-bedded quartzitic rock. According to H. H. Adair the following beds are penetrated in the vicinity of Marshall, Minn.:

Section in wells about Marshall, Minn.

	Feet.
Blue clay, with sand streaks	0–70
"Soapstone," light colored	70–170
"Soapstone," dark colored	170–270
"Black sand" or sandy shale, with flow of soft water	270–295
"Soapstone"	295–415
Sandstone, with hard water under high pressure	415–425+

The bed of light-colored rock at 70 to 170 feet may represent the Niobrara chalk rock, and the lowest sandstone appears to be Dakota.

The shale exposures on the east side of Bigstone Lake, a mile from its upper end, have been examined by J. E. Todd, who finds that they are lead-colored shales containing biscuit-shaped concretions, but no fossils. Probably they are of later Carlile age.

At Whiterock, in the northeast corner of Roberts County, about 20 feet of white "chalk" is reported at a depth of 280 to 300 feet, underlain by 200 feet of "soapstone" lying on granite. This white "chalk" probably represents the Greenhorn limestone of the Benton group. In the wells of Browns Valley, Minn., 362 feet of Benton clays, dark at the base, were penetrated to gravels and sands, presumably Dakota, which yield a flow.

In the outcrops of the formations of the Benton group fossils occur in considerable number. Along Missouri and Big Sioux rivers the Greenhorn limestone member contains vast numbers of *Inoceramus labiatus*, and the associated shales are highly fossiliferous in many places, notably in the bluffs of the Missouri opposite Vermilion. Todd has found many shark's teeth in the exposures of the upper sandstone in Davison County, and reports the occurrence of a fragment of *Prionotropis* in the dark shale on the east side of James River 1½ miles north of Elm Spring. Fossils are reported from some of the wells, notably the Ashmore well southwest of Artesian, near the bottom of which *Mactra* and *Fasciolaria* were obtained. In the well at Farwell shark's teeth were obtained at a depth of 400 feet. In the well 2 miles north of Woonsocket, at 580 feet below the surface, were

obtained abundant fragments of fossiliferous limestone, which T. W. Stanton reports to contain a small *Nucula* with striated surface, which may be the young of *N. cancellata* M. and H., a young *Mactra*, and numerous *Lucinæ* of undetermined species. These were found 250 feet below the chalk and 100 feet above the main flow.

NIOBRARA FORMATION.

The Niobrara formation is a prominent feature in the bluffs of Missouri River above Yankton, especially about the mouth of Niobrara River. It shows almost continuously as far as the great bend, where it passes beneath the Pierre shale at water level. It underlies the drift along the James River valley as far north as Letcher, westward beyond Plankinton, and eastward to Big Sioux River in Hutchinson, Turner, Lincoln, Yankton, Clay, and Union counties, although in the higher part of Turkey Ridge it is probably capped by a small outlying area of Pierre shale. In central Davison, northern Turner, and Lincoln counties it abuts against the quartzite of the underground ridge, on top of which it also lies in detached areas in portions of Hanson, McCook, Minnehaha, and Moody counties. It also appears to extend across the greater part of the northwesternmost counties of Iowa, and along the Iowa-Minnesota state line. The formation is cut through by the Missouri below the mouth of James River, by the Big Sioux below Canton, and by the James from a point north of Mitchell to the center of Hutchinson County. It appears to extend along the east slope of the coteau in the valley of the Minnesota in Grant County, but is there covered by drift.

The formation consists mainly of chalk in the southeastern part of the State, but portions of it grade into shale, which appears to replace the chalk to the north. It is owing to this change in character that very few well borings in the north-central counties report any chalk. The purer material is white or gray when dry, although often dull drab when freshly excavated. It weathers to a bright straw or bright buff color, which is a conspicuous feature in its exposures. It is in greater part massively bedded and is very fine grained and uniform in texture. It is extensively employed for building, being easily quarried and readily shaped by an ax or a saw into suitable building blocks. The chalk consists largely of tests of minute animals, Foraminifera and coccoliths similar to those of the chalk of Europe, mixed with varying amounts of clay and very fine sand. The material was deposited in moderately deep, nearly clear water, without strong currents or other conditions which would bring much admixture of land waste.

In the bluffs along the Missouri, near the mouth of Niobrara River, the locality from which the formation was named, it rises in cliffs 50 to 80 feet high, whose light-buff color is in striking contrast to the

dark slopes of the Pierre and Benton shales. Exposures are numerous along the river from the mouth of the James nearly to the great bend. On James River and the lower portions of its larger branches the chalkstone is exposed at intervals from Scotland northward to Firesteel Creek in Davison County. There are many exposures on Firesteel Creek northwest of Mitchell and on Enemy and Twelvemile creeks southwest and south of Mitchell. It also appears on Wolf Creek, on Dawson Creek near Scotland, on James River below the mouth of Wolf Creek, and east of Mitchell. It is reported in extensive exposures on Clay Creek, 12 miles northeast of Yankton, on Brule Creek northeast of Vermilion, to the northwest of Canton, and on Split Rock Creek, 2 miles north of Brandon.

Chalky portions of the Greenhorn limestone have been included in or mistaken for the Niobrara by some geologists, an error which has produced considerable confusion in the literature relating to the geology of the eastern portion of this region. The Niobrara formation is characterized by the occurrence of small oysters known as *Ostrea congesta*, which usually occur in colonies, and locally on the shells of large fossils, constituting an impure limestone. The Greenhorn limestone, as has been explained, is characterized by the occurrence of large numbers of *Inoceramus labiatus*, a form which occurs sparingly, if at all, in the Niobrara.

The thickness and structural relations of the Niobrara formation have been determined in part by well borings. It is a prominent feature in the wells in Davison County and in the regions to the south, where it consists chiefly of chalkstone; but to the north, as before stated, the chalkstone appears to give place to shale, so that, though undoubtedly existing in the northeastern portion of the State, it is seldom recognized by the well borers. In Yankton County the wells begin in lower beds and soon pass into the underlying Benton deposits. In Bonhomme County the Layton well in the highlands northwest of Springfield appears to have entered the top of the formation at a depth of 90 feet and to have continued in it for 300 feet, including 20 feet of hard limestone at the base. In the town well at Scotland 120 feet of chalk are reported, but in that region some of the top of the formation has been removed by erosion. At Turkey Ridge, in the northeast corner of the county, in one well 215 feet of chalk were reported; at Hurley 100 feet were passed through, and in numerous wells in the central and southern portions of Turner County equal amounts of chalk were recorded.

In Hutchinson County the thickness is considerably diminished as the uplift is approached, but in the western portion of the county, where the Pierre shale overlaps, the full amount remains. In the well at Tripp 275 feet were reported, extending from 25 to 300 feet

in depth, but probably this amount includes much of the yellow clay of the lower part of the drift. In Douglas County the formation appears to average nearly 100 feet. It is reported to extend from a depth of 190 to 300 feet in a well four miles north of Delmont, consisting of blue shaly chalk above and white chalk below, lying on the sandstone of the Carlile formation. In Charles Mix County the formation is not very definitely reported by any of the well drillers, except in the Hammer well west of Castalia, where it is claimed that chalk extends from 87 to 630 feet in depth, surely a great exaggeration of its true extent. In Brule County the formation appears to average 200 feet in thickness. In Aurora County from 100 to 150 feet are reported, except in the northwestern portion of the county, where the formation has suffered considerable erosion and only from 40 to 60 feet remain. In Davison County nearly the entire surface of the formation has been subjected to erosion, for it lies next below the drift. It is usually entered at 20 to 50 feet below the surface and varies in thickness up to 260 feet, which is reported in wells in the southwest corner of the county. In Hanson County the formation is very thin, and is absent over the greater part of the summit of the buried quartzite ridge.

In Sanborn County the formation varies greatly in thickness. To the southeast it has been partly removed by erosion, and to the north it appears to thin under the Pierre shale. In the McCurdy well at Letcher it is reported to be 175 feet thick, and in the Ryan well near by to be only 70 feet. The latter figure is probably nearer the truth, for in the Ryan well the limits of the chalk are clearly indicated by the underlying characteristic sandstone of the Carlile formation. In the Woonsocket well the only chalk reported is a layer 24 feet thick from 412 to 436 feet.

In Miner County the chalk appears to be well characterized, having a thickness of 70 to 120 feet or more, lying under drift to the southwest and under the Pierre shale to the north. At Canova it is reported at a depth of 120 to 150 feet, lying under drift or a small thickness of shale and having a thickness of 50 to 80 feet. In Kingsbury County the only reference to chalk in any of the records is in the Matthews well, 4 miles northeast of Carthage, where it is reported as extending to 493 feet, and in the Welch well, 3 miles northwest of Carthage, where its top is 420 feet deep. In Beadle County chalk is mentioned in a few of the records, but apparently it has given place for the most part to shale which is not distinguished from the adjoining Pierre or Benton. In Spink County some limestone is reported at an average depth of about 450 feet, underlain by sandstone reported to be at the top of the Benton, and this may represent the chalk horizon. "Limestone" reported in the wells at Aberdeen from 515 to 530 feet

and in those at Andover from 575 to 590 feet may possibly represent the Niobrara. In the Missouri Valley above Chamberlain the chalk is not reported by the well borers, doubtless giving place rapidly to gray shales, as in the northern James River valley region just described.

In the northeast corner of the State chalk rock, which appears to be of Niobrara age, is reported from some wells in southeastern Grant County on slopes above shales yielding *Prionocyclus woolgari*. The wells in which this rock is found are from 10 to 12 miles south of Milbank.

PIERRE SHALE.

The Pierre shale extends across the greater part of eastern South Dakota, appearing extensively in the slopes of the Missouri Valley but being mostly covered by drift deposits in the country to the east. Its maximum thickness is probably above the mouth of Cheyenne River, where it is overlain by the Fox Hills sandstone. To the east its surface has been more or less deeply eroded, especially in the area of uplift adjacent to the lower portions of the James and Big Sioux valleys, where it has been entirely removed from a zone of considerable width.

The formation consists almost entirely of dark-gray clay, hardly sufficiently compact to be termed shale and presenting but little variation in its character from top to bottom. It contains scattered concretions, numerous masses of pyrites, thin bodies of sandstone, and some local chalky deposits to the south. Many of the deep wells pass through the formation for several hundred feet, the amount increasing gradually to the north and west of Davison County. In the slopes of the Missouri Valley above the great bend 500 feet of the formation are to be seen, but below the great bend, as the underlying Niobrara chalk rises in the banks, the shale diminishes in thickness and a short distance below the mouth of Niobrara River thins out and disappears. The many variations in its thickness are due mainly to the extensive and irregular erosion suffered by the shale previous to the deposition of the glacial drift by which it is now mostly covered.

It is several hundred feet thick in the ridge lying between James and Missouri rivers, in Charles Mix, Douglas, and Brule counties. At Armour there are probably 170 feet of the formation; 10 miles north of Armour, 300 feet; in the western portion of Aurora County, 350 feet; in Brule County the amount diminishes somewhat, owing to the local uplift; in approaching the uplift in eastern Aurora County the formation thins out entirely; in the highlands of Jerauld County 300 feet are reported. The amount increases on the higher lands, and the increase continues toward the north in the highlands

between Missouri and James rivers; but owing to the indefiniteness of the well records as to the limits of the Niobrara formation in that direction the precise thickness of the Pierre can not be stated; apparently it is more than 1,000 feet.

In the James River valley about 500 feet are reported in the wells at Aberdeen and Andover and about 400 feet in Spink County; but here also the uncertainty as to the position of the Niobrara formation prevents a clear recognition of the lower limit of the Pierre in the reports of the well borings. In Beadle County the amount is materially less and diminishes to the south until finally the formation thins out in the center of Davison County, on the anticlinal uplift of the Mitchell region.

East of the James River valley, north of this uplift, the formation extends eastward to the margin of the Minnesota Valley, underlying the high coteau, where it has a thickness of several hundred feet. In Kingsbury County it appears to have a thickness of about 100 feet in the highlands on the east, although its limits in the De Smet well are not indicated by the record. It appears to extend southward through Lake County to the quartzite ridge, for it presents considerable thickness in the well at Madison. It also appears to extend eastward into Minnesota, for Pierre fossils have been found in the western slopes of the Minnesota Valley; and although it has been stated by Todd that probably all these fossils so far reported were found in the glacial drift, yet they have not traveled far. About Taunton, in Lyon County, the fossils are found below the level of the Benton group, and there, as about Milbank, they are inclosed in drift deposits.

Exposures of the formation are exceedingly rare east of the immediate slopes of the Missouri Valley. In the region of thin drift about Ree Heights and to the south the formation outcrops for some distance, and it appears again south of Swan Lake in Potter County, northeast of Gann Valley, and on Turtle Ridge, near Wessington Springs. Todd states that shallow streams cut into it in western Brown County, northwest of Aberdeen and on Willow Creek and its north branch northwest of Westport; in southeastern Brown County, 5 to 8 miles south of Groton; along James River northeast of Redfield; in northwestern Day County, 2 miles and 4 miles north of Pierpont; and extensively north and south of Groton. Dark shale, probably belonging to the Pierre, is reported in the northeast corner of Yankton County, where it lies on the Niobrara at an altitude of 1,510 feet, and it is believed to extend thence under a considerable portion of Turkey Ridge, beneath the drift. At the cement works 3 miles west of Yankton it caps the Niobrara chalk rock, a relation which it presents in numerous exposures for many miles along the river.

FOX HILLS SANDSTONE.

There is no good evidence of the existence of the Fox Hills sandstone east of the Missouri, south and east of Campbell County. It is suggested by Todd that some sand on the high hills north of Forest City and the fine yellow sand along Swan Creek southwest of Bangor may be Fox Hills, and that remnants of this formation may be found in the Faulkton, Bowdle, and Koto hills.

TERTIARY DEPOSITS.

Evidence as to the existence of the Tertiary formations in eastern South Dakota is meager. On the summits of the Bijou Hills are caps of distinctive green quartzite of later Tertiary age lying on light-colored sands and sandy clays. Another area of the quartzite is found on the high ridge due east of Greenwood.

Fossil fish of supposed Oligocene age have been obtained from the high ridge southwest of Ree Heights, but the extent of the deposit in which they were found has not been determined. According to Todd, the high ridge just west of Wessington Springs contains deposits of sandstone supposed to be older than the drift and probably of the same age as the quartzite on the Bijou Hills. It shows the same general structure, even carrying some beds of grit between the finer layers, and lies on lead-colored Pierre clay. Doubtless much of eastern South Dakota was originally covered by Tertiary deposits, but they were removed by the deep and widespread erosion of early Quaternary time, although in some areas they may remain, mostly covered by the glacial drift. A tooth obtained by Todd from a 175-foot well at Trent, Moody County, is regarded as Tertiary by W. B. Scott.

QUATERNARY DEPOSITS.

That portion of South Dakota lying east of the Missouri is covered in greater part by a thick mantle of Quaternary deposits, mainly of glacial origin. There are several lines of morainal ridges, a nearly continuous sheet of glacial till, extensive glacial-lake deposits, and alluvial accumulations of Pleistocene and of Recent age. These formations have been described in detail by J. E. Todd, to whose publications the reader is referred.[a]

[a] The moraines of the Missouri coteau and their attendant deposits: Bull. U. S. Geol. Survey No. 144, 1896; The moraines of southeastern South Dakota and their attendant deposits: Bull. U. S. Geol. Survey No. 158, 1899; Geology and water resources of a portion of southeastern South Dakota: Water-Supply Paper U. S. Geol. Survey No. 34, 1900; and folios mentioned in footnote on page 32.

UNDERGROUND WATERS.

GENERAL CONDITIONS.

The thick succession of sedimentary formations underlying South Dakota includes porous strata containing large volumes of water. These water-bearing deposits comprise widespread sheets of sandstone or sand ranging from Cambrian to Tertiary in age, the alluvial sands in the bottoms of valleys, and the sands of the sand hills. The sandstones are in many places several hundred feet thick and lie

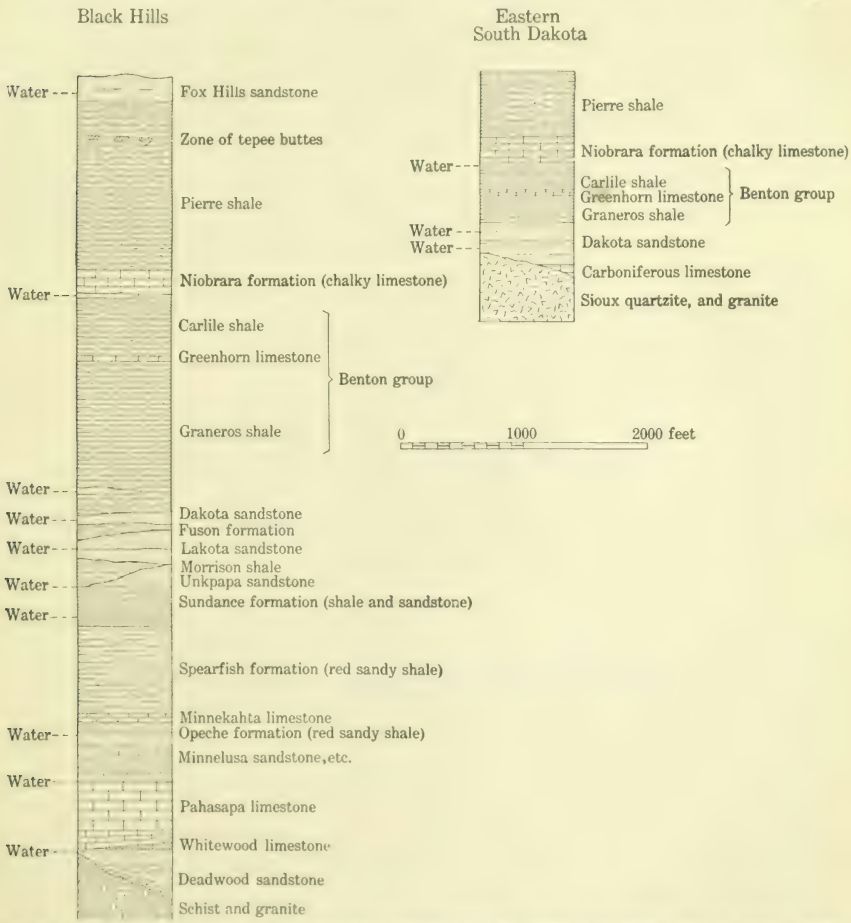


FIG. 1.—Columnar sections showing the water horizons in the Black Hills region and in eastern South Dakota.

between bodies of relatively impermeable shales or limestones, so that they present favorable conditions for artesian waters. To the west they are upturned on the uplift of the Black Hills and outcrop at high altitudes; to the east some of them come to the surface and others thin out. The principal structural relations in the State are shown in the three cross-sections of Plate VI, and the succession of water-bearing horizons is shown in the columnar sections of figure 1.

Part of the rainfall and stream flow passes into the sandstones in their elevated outcrop zones in the Black Hills and flows eastward through the interstices of the rock in its extension under the lower lands. Some of it finally escapes in springs in the outcrops in eastern South Dakota and Nebraska. In such water-bearing strata as the Dakota and underlying sandstones, which are overlain by a thick mass of impermeable deposits, the waters are under great pressure, for the intake zone has an altitude of about 4,000 feet and the region of outflow is only 1,000 to 1,200 feet above sea level. The evidence of this pressure, as found in many wells in eastern South Dakota, is conclusive that the water flows underground for many hundreds of miles. Several wells show surface pressures of 175 to 200 pounds to the square inch, the latter indicating a pressure of 780 pounds to the inch at the bottom of the well. Such pressures can be explained only by the hydrostatic influence of a column of water extending to a high altitude on the west. If it were not for the outflow of the water to the

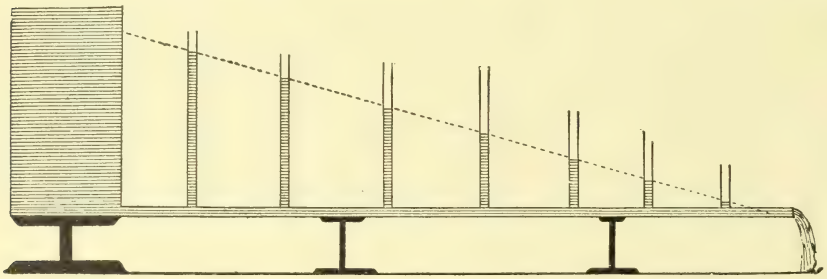


FIG. 2.—Diagram of apparatus for illustrating the declivity of head of liquids flowing from a reservoir. The shaded portions are water.

east and south the initial head which the waters derive from the high lands of the intake zone would continue under the entire region, but owing to this leakage the head is not maintained, and there is a gradual diminution toward the east known as "hydraulic grade," a slope sustained by the friction of the water in its passage through the strata. Figure 2 shows a simple apparatus which illustrates the general conditions.

Another factor which undoubtedly somewhat influences the hydraulic grade in the Great Plains region is a certain but unknown amount of general leakage through the so-called impermeable strata, all of which permit the passage of an appreciable proportion of water, especially when under great pressure. The conditions shown in figure 2 are closely similar to those found in the Dakota sandstone, which is the principal water-bearing stratum underlying the Great Plains. From the altitudes of outcrops of this sandstone and pressures observed in many wells the lines in figure 3 and Plate XI have been constructed to indicate the observed and probable head of the

artesian waters. In areas of flow the pressure in pounds at any point may be ascertained by subtracting the altitude of the land from

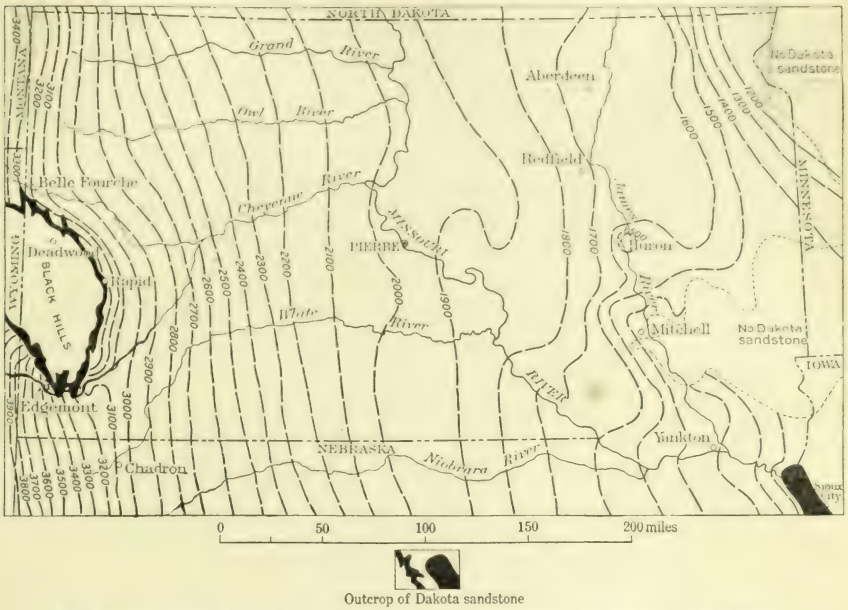


FIG. 3.—Diagram of South Dakota, showing hydraulic gradient by contour lines of head.

the altitude of the head and dividing by 2.3 (the height in feet of a column of water 1 inch square weighing 1 pound). In areas too high for flow the depth to the point to which the water may be

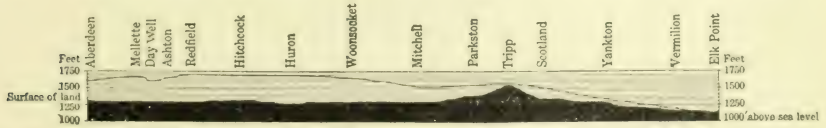


FIG. 4—Profile from north to south down James River valley, showing hydraulic grade. The land profile is shown in solid black; the altitude of the head of the artesian waters by the line.

expected to rise may be found by subtracting the altitude of head from the altitude of the land. Figure 4 shows the hydraulic grade down the James River valley.

WATER HORIZONS.

DAKOTA AND ASSOCIATED SANDSTONES.

The Dakota sandstone is the most widely extended and serviceable water-bearing formation in South Dakota and it is the principal source of artesian flow in the many wells. It consists largely of sandstone, and averages about 300 feet thick. The sandstone is in

thick sheets separated by deposits of clay or shale. In the Black Hills there are two water-bearing sandstones separated by a shale known as the Fuson formation, which separates the Dakota sandstone above from the Lakota sandstone below. In the Black Hills the Dakota lies on various sediments, as shown in the first section in figure 1. To the east these formations thin out and in the eastern part of the State the Dakota sandstone lies on Sioux quartzite or on granite, except to the extreme southeast, where Carboniferous limestones and other rocks intervene. Apparently the Lakota sandstone and overlying Fuson formation are also absent to the east, but the evidence on this point is not conclusive, at least for the greater part of eastern South Dakota.

The Dakota water horizon is believed to underlie all of the State of South Dakota except in the Black Hills uplift, the high underground ridge of Sioux quartzite extending eastward from Mitchell and a portion of the Minnesota Valley. The areas in which the formation is absent are shown on Plate XI and figure 3. The limits on the east, however, are determined only approximately on the evidence of widely scattered wells and outcrops.

SANDSTONES OF THE BENTON GROUP.

Although the Benton group consists mostly of shale, it includes beds of sandstone containing more or less water which is the source of supply for some artesian wells in the eastern portion of the State. Many of the wells, also, which obtain their principal supplies from the Dakota sandstone find a first and some of them a second flow in sandstones in the overlying Benton. The principal water-bearing sandstone is a bed which occurs near or at the top of the formation. In some places it immediately underlies the Niobrara chalk; in others it is separated from that formation by black shale which locally attains a thickness of 100 feet. The upper sandstone of the Benton is usually less than 25 feet thick, but ordinarily it is coarse and contains water in moderate amount and under considerable pressure. The sandstone outcrops along Firesteel, Enemy, and Twelvemile creeks and James River in Davison, Hanson, and Hutchinson counties. Its greatest thickness, 85 feet, is attained in the southwestern portion of Davison County. In wells near Armour it varies from 35 to 60 feet thick. The lower sandstones in the Benton group are much less definite in position and occurrence, but they are represented in many of the well records in the James River valley.

MINNELUSA SANDSTONE.

The Minnelusa sandstone outcrops along the slopes of the Black Hills uplift and undoubtedly it underlies an area of considerable extent

in the adjoining plains of western South Dakota. The formation consists largely of sandstone (see Pl. IV, A), some of which is porous and water bearing. The facts that numerous springs emerge from the formation on the higher slopes and that many of the streams crossing the outcrop of the sandstone sink into it in whole or in part, indicate that it has great capacity as a water bearer. Owing to the steep dips on the sides of the Black Hills uplift the formation is rapidly carried to a depth too great to be reached by ordinary well boring under the plains, but in the Red Valley, where its depth beneath the surface is less than a thousand feet, it may prove to be an important source of water supply. Its capabilities have been tested in the canyon south of Spearfish, where a satisfactory flowing well was obtained from the lower sandstones. The top sandstone usually is coarse grained in the northern hills and probably contains water in considerable amount. It lies about 800 feet below the top of the red beds in the northern Black Hills and about 850 feet below in the southern Black Hills, as shown in the boring at Edgemont. In the boring at Minnekahta the formation yielded no water supply, but in the deep boring at Edgemont it was found to contain considerable water though not under sufficient head to afford a flow. It would appear that in the southern portion of the Black Hills area, and also on the western slope, as indicated by the Cambria well, the formation is too fine grained and too closely cemented by carbonate of lime to yield much water.

FOX HILLS AND OVERLYING SANDSTONES.

The sandstones in the Fox Hills and overlying formations contain considerable water, but the source of supply is local and the land is too elevated to afford much promise of artesian flow. Possibly flowing wells may be obtained from these sandstones in the Little Missouri Valley and on the lower lands in the upper portion of the valley of Grand River.

DEADWOOD SANDSTONE.

The Deadwood formation in the Black Hills uplift consists largely of sandstone which undoubtedly contains water. There is only a restricted area, however, in which it will be practicable to reach the formation by wells, for it descends rapidly to great depths along the slope of the uplift. In the Red Valley the top sandstone lies at a depth of about 2,000 feet. The formation has recently been penetrated by a well at Edgemont, and at a depth of 2,920 to 2,980 feet yields a 300-gallon flow.

CHADRON FORMATION.

The Chadron formation underlies the badlands area in the southwestern portion of South Dakota and consists mostly of sands and

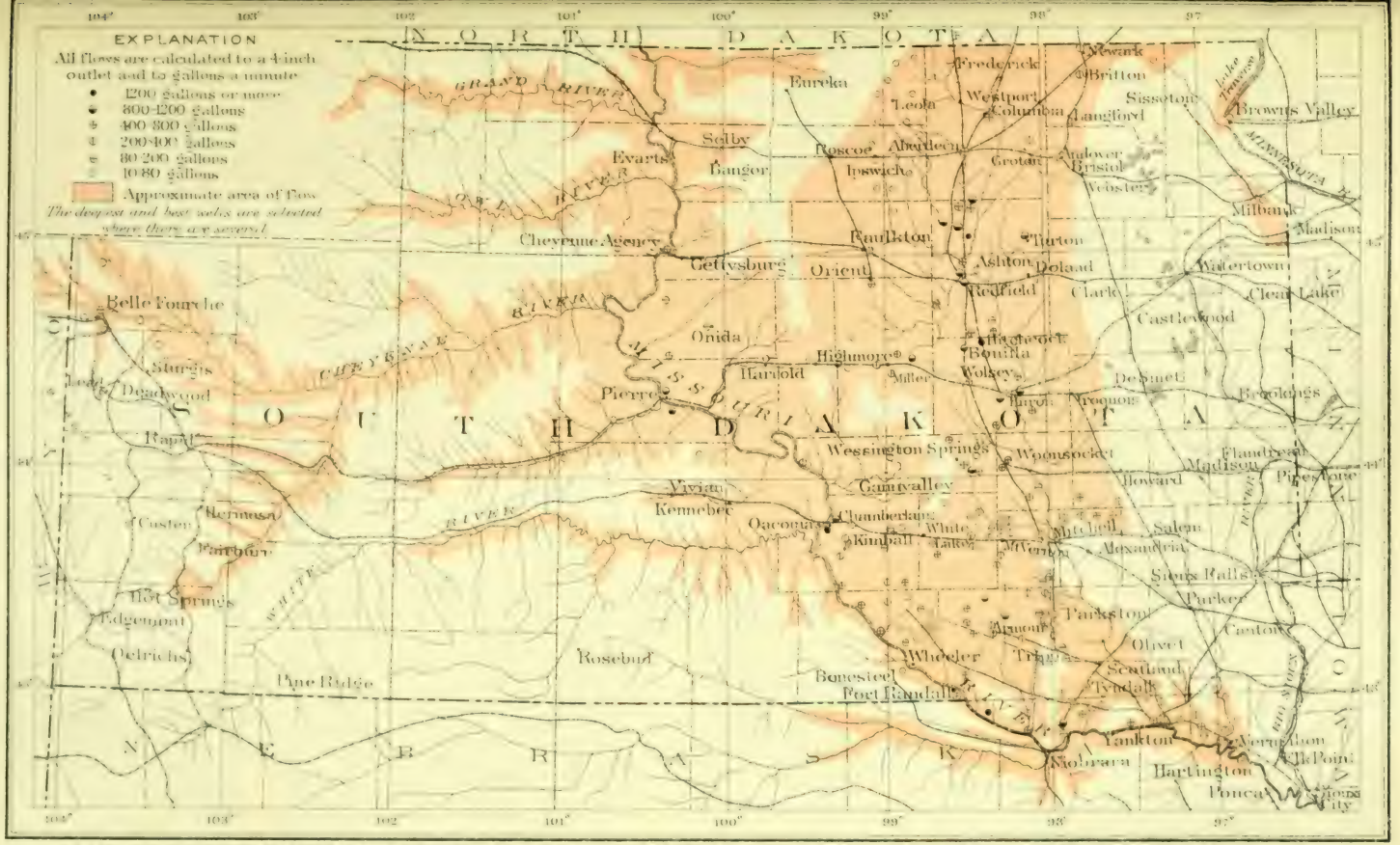
soft sandstones which contain considerable water. This water, however, has but little head, for it is of local origin. It yields springs at many localities in the badlands, and water could be obtained by shallow wells; possibly the formation might afford weak flows along the White River valley in the western portion of the Pine Ridge Indian Reservation.

DEEP WELLS AND WELL PROSPECTS IN SOUTH DAKOTA.

INTRODUCTORY STATEMENT.

As explained in a previous paragraph, there are several sources of underground waters in South Dakota, but the Dakota and associated sandstones furnish the supply for most of the deep artesian wells. Owing to the high elevation of its intake zone along the Black Hills this water is under great pressure and will afford flows in all but the highest lands except in the southeast corner of the State, where the head is lost in approaching the area in which the sandstone reaches the surface. Over a thousand wells have been sunk east of the Missouri, most of them being from 500 to 1,000 feet deep. There is also a group of flowing wells about Belle Fourche, and recently the flow has been struck by wells in the valley of Bad River. The aggregate flow from these wells is estimated to be about 7,000,000 gallons a day. It is believed by some persons that this great draft is diminishing the available supply of the underground water, but there is no evidence as yet that this is the case except locally in districts where there are numerous wells. Individual wells often diminish in flow and pressure, but usually this is due to leakage or clogging, and new wells in the same vicinity show the same flow and pressure as were found in the older ones. However, it is probable that with increased numbers of wells and long-continued flow the available artesian supply will eventually be materially diminished.

The area in which flows may be expected from the Dakota and associated sandstones is shown on the map (Pl. XI), which also shows the depths to the sandstone, the location and depths of wells which have been sunk, and the altitude of the head of the water. The last-named item has been determined from the altitude of the outcrop in the Black Hills and the observed pressures in wells. These pressures are converted into head by multiplying the number of pounds to the square inch by 2.3 (the height in feet represented by the pressure of 1 pound) and adding the altitude of the land. This gives the altitude above sea level to which the water would rise in pipes or up the slopes of adjacent higher lands. Lines are drawn on the map for every 100 feet of altitude of head and show a regular down grade from the Black Hills to the southeast corner of the State. Wherever



MAP OF SOUTH DAKOTA ARTESIAN AREA, SHOWING RELATIVE VOLUMES OF FLOWS FROM WELLS

BY N. H. DARTON

1908

data are lacking lines have been introduced on the assumption that the gradient is regular. Where the altitude of the head is greater than the altitude of the surface the wells will flow, and the flow area represented in Plate XI has been deduced in this manner from the headlines and the topographic contour lines. As the precise gradient of head is not everywhere accurately ascertained, and as some of the topographic data are only approximate, the flow area can be indicated only approximately in some portions of the State. There is, moreover, considerable variation in pressure in the different flows at various depths, and in many wells where the water in the upper sandstones will not have sufficient head to flow, a deeper water will rise to the surface. The data are sufficient to indicate that flows may be expected in a large area in which no wells have yet been sunk in the many valleys of the central portion of the State, in the region north and northwest of Belle Fourche and east of the Black Hills. The depths as shown in Plate XI are deduced from the structure (Pl. XIII), thickness, and distribution of the formations and the records of wells. The variations in thickness appear to be regular and most of the structure is evident on the surface, but it is probable that here and there some difference will be found between the true and the predicted depth. Moreover, in many places it is necessary to sink deeply into the water-bearing sandstones before a satisfactory flow is obtained. Relative volumes of flows are shown in Plate XII.

AURORA COUNTY.

Aurora County lies mainly on the divide between the valleys of James and Missouri rivers. Its surface is largely covered by glacial deposits, which lie on Niobrara chalkstone to the east and on Pierre shale to the north, west, and south. The Dakota sandstone underlies the entire area and contains a large volume of water under pressure sufficient to afford artesian flows, except possibly in the highest hills in the extreme northwest townships and a small area in the south-central part of the county. The sandstone dips gently to the south in the southern part of the county and to the north in the northern part, arching over a gentle anticline that rises above the underground ridge of Sioux quartzite extending westward from the Alexandria and Mitchell region.

The depths to the sandstone vary from 400 feet near the center of the eastern margin of the county to 550 feet at Plankinton, 800 feet or more in the central, north-central, and southern portions of the county, and somewhat over 1,000 feet in the northwest corner. The Dakota sandstone contains several flows of water, the lowest ones having the largest volume and highest pressure. The volume varies considerably and appears to be less over the underground quartzite ridge which extends east and west in the center of the county. The

following is a list of the principal wells, with statements as to their depths and other features:

Representative artesian wells in Aurora County.

	Depth.	Diameter.	Yield per minute.	Remarks.
	Feet.	*Inches.*	*Gallons.*	
J. Asmuss, NW. ¼ sec. 1, T. 101, R. 64	630			
Peter Mathig, SW. ¼ sec. 17, T. 101, R. 66	960	2	60	
Anton Hettinger, NE. ¼ sec. 3, T. 101, R. 66	800	2	50	
James Dunbar, SW. ¼ sec. 6, T. 101, R. 66	730	2	30	
Sec. 1, T. 102, R. 63	300			
Sec. 10, T. 102, R. 63	536			
J. W. Ryan, NE. ¼ sec. 10, T. 102, R. 63	613	2	3	
Sec. 11, T. 102, R. 63	460			
SE. ¼ sec. 17, Crystal Lake Township	850	4½	600	Pressure 55 pounds.
Sam Edelman, NW. ¼ sec. 19, T. 102, R. 64	800	3–2	40	Pressure 78 pounds.
Do	800	3–2	40	
John Scales, SE. ¼ sec. 29, T. 102, R. 64	600	2	8	
William Edelman, sec. 25, T. 102, R. 65	795	2	10	Pressure 40+ pounds.
George Severance, SW. ¼ sec. 7, T. 102, R. 66	800	2	120	
Mike Galles, sec. 17, T. 102, R. 66	835	4½	400	
Philip Eyer, T. 103, R. 63, 5 miles southeast of Plankinton.	705	3	200	
Evon Raesley, SW. ¼ sec. 28, T. 103, R. 63	716	3	200	
George Saville(?), T. 103, R. 63	530	2	30	
Sam Swenson, sec. 13, T. 103, R. 63	420	2	30	
J. D. Barton, SW. ¼ sec. 8, T. 103, R. 63	755	3	100	Pressure 80 pounds.
J. R. Mabbot, sec. 26, T. 103, R. 63	530	2	10	
L. Mabbot, sec. 26, T. 103, R. 63	490	2	10	
Leonard Scott, sec. 35, T. 103, R. 63	484	4–3		
C. R. Cook, sec. 32, T. 103, R. 63	623	3–2	15	
Sec. 4, T. 103, R. 63	500			
Sec. 8, T. 103, R. 63	755			
Sec. 9, T. 103, R. 63	470			
Sec. 10, T. 103, R. 63	900	2	4+	
Do	425			
Sec. 11, T. 103, R. 63	440			
Sec. 12, T. 103, R. 63	390			
Sec. 13, T. 103, R. 63	380			
Sec. 24, T. 103, R. 63	425			
Do	378			
Sec. 25, T. 103, R. 63	420			
Sec. 35, T. 103, R. 63	507			
City of Plankinton, sec. 22, T. 103, R. 64	795	4½		
Plankinton Township well, sec. 22, T. 103, R. 64	775	4½	200	Pressure 55 pounds.
Plankinton	830	4½–3	225	
Thos. Mullivan, NW. ¼ sec. 29, T. 103, R. 64	715		1,200	
O. R. Auld, Plankinton	745	4	60	
Sec. 27, T. 103, R. 64	765			
Hans Hanson, SW. ¼ sec. 31, T. 103, R. 65	830	2	40	
A. H. Henneaus, sec. 34, T. 103, R. 66	842	6		
White Lake, T. 103, R. 66	863	4	150	Pressure 35 pounds.
White Lake, sec. 10, T. 103, R. 66	900	2	4	Pressure 12+ pounds; city well No. 2.
White Lake, sec. 11, T. 103, R. 66	830	2	4	Pressure 10± pounds; city well No. 3.
James Ryan, sec. 22, T. 104, R. 63	525	4½–3	168	
O. Scott, sec. 1, T. 104, R. 63	470	2	4	
A. D. Dougan, sec. 21, T. 104, R. 63	523	4½	150	Pressure 45 pounds.
B. H. Sullivan, sec. 21, T. 104, R. 63	525	4½	150	
Sec. 2, T. 104, R. 63	740			
Sec. 3, T. 104, R. 63	508			
Sec. 10, T. 104, R. 63	440			
Sec. 15, T. 104, R. 63	465			
Sec. 17, T. 104, R. 63	540			
Sec. 20, T. 104, R. 63	530			
Sec. 21, T. 104, R. 63	575			
Sec. 23, T. 104, R. 63	364			
Sec. 26, T. 104, R. 63	426			
Sec. 35, T. 104, R. 63	490			
Do	450			
Sec. 34, T. 104, R. 64	590			
Do	545	2	2½	
H. Koeman, jr., sec. 26, T. 104, R. 65	728	2	84	
A. W. Closson, sec. 3, T. 104, R. 66	922	2	75	
S. H. Bullock, sec. 2, T. 104, R. 66	844	2	150	
Sec. 24, T. 105, R. 63	487	2	32	

MAP OF SOUTH DAKOTA, SHOWING THE STRUCTURE OF THE DAKOTA SANDSTONE

BY N. H. DARTON

Representative artesian wells in Aurora County—Continued.

	Depth.	Diameter.	Yield per minute.	Remarks.
	Feet.	*Inches.*	*Gallons.*	
George Scott, T. 105, R. 63	475	2	5	
Sec. 2, T. 105, R. 63	400			
Sec. 7, T. 105, R. 63	580			
Sec. 24, T. 105, R. 63	500			
Sec. 26, T. 105, R. 63	490			
Do	475			
Sec. 28, T. 105, R. 63	508			
Do	560			
Sec. 35, T. 105, R. 63	620			
Sec. 2, T. 105, R. 64	640			
Sec. 22, T. 105, R. 64	563			
M. E. Lewis, SW. ¼ sec. 32, T. 105, R. 66	1,222	3	Few.	On high land; barely flows.
Mullen Bros., sec. 24, T. 105, R. 66	953	2	60	

Some representative deep-well records in Aurora County are as follows:

Record of well of J. W. Ryan, NE. ¼ sec. 10, T. 102, R. 63.

	Feet.
Drift	0– 80
Shale (Pierre?)	80–104
Chalk rock (Niobrara)	104–214
Sand rock and sand; soft water	214–324
Shale	324–536
Sandstone	536–566
Shale	566–576
Sandstone with large flow of water	576–580
Shale	580–614

The sand rock at 214 to 324 feet is at the top of the Carlile shale of the Benton group, which extends to the probable top of the Dakota sandstone at 536 feet.

Record of Raesley well, SW. ¼ sec. 28, T. 103, R. 63.

			Feet.
Drift			0– 90
Chalk rock (Niobrara)			90–230
Sand rock, with soft water			230–260
Blue shale			260–308
Hard layers (probably Greenhorn limestone)			308–328
Shale	Graneros		328–477
Hard sandstone; first flow			477–489
Blue sandy shale			489–605
Sand rock; second flow, 100 gallons	Dakota		605–610
Shale, with hard layers			610–675
Sandstone; third flow, 100 gallons			675–705
Gray shale			705–716

In this record the sandstone at the top of the Carlile shale at 230 feet is only 30 feet thick, and its amount is found to be extremely variable in other wells in the vicinity.

Record of well of J. Asmuss, NW. ¼ sec. 1, T. 101, R. 64.

	Feet.
Drift and clay	0–250
Chalk rock (Niobrara)	250–398
Sandstone, with soft water	398–430
Shale	430–630
Sandstone and flow	630–632

It is not certain that this well reaches the top of the Dakota sandstone, and it may flow from a first-flow sandstone low in the Graneros shale.

Record of well at Plankinton.

	Feet.
Drift and clay	0–145
Chalk rock (Niobrara)	145–256
Sand and soft water	256–266
Shale, some sandy layers	266–538
Sandstone, with flow	538–543
Shale, probably with a flow at 646 feet	543–763
Sandstone, with main flow	763–793
Quartzite (probably Sioux quartzite)	793–795

It is believed that the top of the Dakota lies at a depth of 538 feet in this well. Quartzite is reported at a depth of 850 feet at White Lake, with the top of Dakota sandstone at 790 feet.

The deepest well in the county so far reported is on the ranch of M. E. Lewis, in the SW. ¼ sec. 32, T. 105 N., R. 66 E. It has a depth of 1,222 feet, but only a light flow, probably owing to the height of the land on which it is situated. Samples of borings at 1,218, 1,220, 1,221, and 1,222 feet were found to be hard sandstone with iron-oxide cement, undoubtedly Dakota sandstone.

BEADLE COUNTY.

Beadle County lies mainly in the James River valley, but its southwest corner extends up the slopes of the higher lands to the west. The surface is covered by glacial deposits varying in thickness from 50 to 300 feet, lying on Pierre clay. This clay is several hundred feet thick and is underlain by the usual succession of Niobrara formation, Benton shales and sandstones, and Dakota sandstone lying on granite and quartzite. The Niobrara formation is so shaly in this county that ordinarily it is not recognized by the well borers as distinct from the adjoining shale. The Benton group includes a bed of sandstone at its top and other thin beds of sandstone lower down, which contain water supplies, the upper sandstone yielding water for pumped wells and the lower sandstone yielding small first flows in the deep wells.

The Dakota sandstone contains a great volume of water under high pressure and affords a supply for a number of wells in all portions of the county. The sandstone lies nearly level, and, as the

country is relatively flat, the variations in depth are not great. The depths of the majority of wells range from 750 to 1,100 feet, the deeper ones extending into the lower beds of the formation, where the flows usually have somewhat greater volume and higher pressure than those in the upper sandstone layers.

The following is a list of representative artesian wells in Beadle County:

Artesian wells in Beadle County.

Township.	Range.	Depth.	Average yield per minute.	Remarks.
		Feet.	*Gallons.*	
109	62	785–916	35–250	Pressure 125 pounds.
109	63	806–856	Many.	
109	64	830–910	45	
		850	45	
110	59	857	50	
110	60	930	930	Pressure 100 pounds.
		790	111	
		770	35	
110	61	879	150–200	Pressure 60 to 100 pounds.
		900	500	Pressure 125 pounds.
110	62	784–1,139	350–2,250	Pressure 120 to 165 pounds; Huron town wells.
110	63	840	.....	
110	64	847	100	
110	65	870	50	
111	59	940	20	
111	59	925	50	
111	61	792	200	
		836	360	
111	62	744–788	300	
111	63	780–918	45–114	
111	64	784–870	43–100	
		930	330	Pressure 137 pounds; Wolsey well.
111	65	1,000	80	
112	59	913, 933	35	
112	60	779	400–600	Pressure 120 pounds.
112	61	778–917	35	
		777	600	Pressure 125 (?) pounds.
112	62	793–817	40–240	Pressure in one well, 50 pounds.
112	63	601–870	16–200	Pressure in one well, 60 to 90 pounds; in another, 20 pounds.
112	64	900	45	
113	60	810	200	Pressure 115 pounds.
113	61	750–810	60–125	
113	62	815	120	
113	63	890	300	Pressure 100 (?) pounds.
113	63	900–912	50	
		953	1,260	Pressure 150 pounds; Hitchcock well.
113	64	980–1,118	20–1,435	Pressure in one well, 175 pounds.
114	59	1,038	8	

BONHOMME COUNTY.

Bonhomme County extends northward from Missouri River into a region of plains and ridges. The greater part of the county is heavily drift covered, but there are extensive exposures of the underlying Niobrara chalkstone in the bluffs along the Missouri River. The higher lands of the ridges east of Choteau Creek are underlain by Pierre shale. The county lies in the Dakota artesian area, but the higher lands in its western portion are too high for flowing wells. In the valleys and on the broad plain in the central and eastern portion of the county there are numerous flowing wells, which obtain supplies of water at moderate depths. There is considerable varia-

tion in the volume of water, a well at Springfield yielding 3,000 gallons a minute, while at Scotland the flow is small, owing to local conditions of diminished thickness and porosity of the sandstone. The following list gives the principal features of the deeper wells in this county from which reports have been received:

Artesian wells in Bonhomme County.

Township.	Range.	Depth.	Average yield per minute.	Remarks.
		Feet.	*Gallons.*	
92	60	885, 920	.....	Pressure in 885-foot well, 30 pounds.
93	58	630–665	95–100	Pressure 42 to 45 pounds.
93	59	530–855	15–252	Pressure 40 to 66 pounds.
93	60	620	700	Springfield city well.
93	60	592	3, 292	Pressure 86 pounds; in Springfield mill.
93	60	828	72	Pressure 86 pounds; city well.
93	61	735–1, 000	25–70	Pressure 12 to 14 pounds.
93	62	862 (?), 897	1, 400–1, 600	Pressure 62 to 58 pounds.
94	58	576–645	11–100	Pressure 40 pounds.
94	59	552–752	13–150	Pressure in 752-foot well, 40 pounds.
94	59	857	1, 000	Pressure 30 pounds; city of Tyndall.
94	61	1, 074⅔	⅓	Pressure 2½ pounds.
95	59	730–828	26–97	
96	58	582–680	9	Scotland wells.
96	59	590–700	Few.	

The well at Springfield is a phenomenal one, with its flow of 3,292 gallons per minute, although its closed pressure is not so great as that of many other wells in the State. It furnishes power for a 60-barrel flour mill by day and for an electric-light plant by night. For awhile it threw sand, and when this finally ceased the flow was thought to have slightly decreased. The city well when finished was for some time allowed to run at full head, and it was then observed that the flow of the mill well was noticeably weakened for the time being.

The first well at Scotland was sunk to a depth of 582 feet, of which the last 52 feet were in "quartzite." The water supply found in sand on the surface of this quartzite was so small that the well was regarded as a practical failure. Not far from the old well another was recently sunk through a hard sandstone bed into clear white sand at 590 feet, but obtained no increase in flow. The Layson well was sunk on the high ridge between Emanuel and Choteau creeks to a depth of 1,074 feet. Only a feeble flow was found, and the pressure was sufficient to raise the water only about 7 feet above the surface. The wells at Tyndall, those in the southeast corner of the county, and those in the Missouri bottom near the mouth of Choteau Creek yield more satisfactory supplies.

The artesian waters in Bonhomme County, except those at Scotland, Layson, and the mouth of Choteau Creek, all appear to come from approximately the same horizon. At Scotland the waters seem to be largely cut off by a ridge of the quartzite bed rock. The Layson well

was apparently sunk to a horizon considerably below that of the group of successful wells to the east and south. The low pressure in this well is due to the height of the land on which the well is sunk, and the small volume of water is no doubt due to some variation in texture, such as occurs locally in the Dakota sandstone. The wells at the mouth of Choteau Creek appear to draw their waters from a horizon somewhat lower than that at Springfield and Tyndall. Probably it is the same horizon as that at which is found the small flow at the Layson well on the ridge to the northeast, but here the sandstone is so porous as to furnish a larger volume of water.

The head of the waters in Bonhomme County is considerably less than it is farther north, for the amount decreases rapidly to the south and east in this region. It appears, however, to be sufficient to bring the water to the surface over all of the county, with the probable exception of the high ridge between Emanuel Creek and Choteau Creek.

The wells in Bonhomme County disclose much diversity in the underground geology. After passing through the drift they enter the chalk rock, which, having an irregular surface and thickness, varies considerably in amount. It is usually underlain by the upper sandstone of the Carlile formation, in some places separated from the chalk by clay, which yields considerable water to some of the deeper pumped wells in the county. The underlying Benton includes beds of limestone and sandstone, the latter locally yielding small first flows. The thickness of the Benton and of the underlying Dakota appears to vary considerably. Under Scotland the Dakota sandstone is very thin. At Springfield it is penetrated for 50 feet, and in the Layson well, on the high ridge west of Springfield, a continuous bed of sandstone is reported at 810 to 1,043 feet, containing but little water and separated from a very hard rock, presumably granite or quartzite, by a small mass of shale. The record of the Scotland well, kindly furnished by A. E. Swan, is as follows:

Record of well at Scotland, Bonhomme County.

	Feet.
Yellow clay	0– 15
Hardpan	15– 20
Blue clay	20– 42
Gray clay	42– 75
Black clay, gravelly	75– 90
Chalk rock	90–130
Yellow sandstone, hard	130–155
Blue shale	155–195
Gray shale	195–350
Yellow lime rock	350–380
Shale and lime	380–415
Sand and shale	415–445

	Feet.
Lime rock	445–451
Sandy mud	451–456
Lime rock, shale, and marl	456–476
Sand rock, with shale streaks	476–510
Red shale and quartzite	510–518
Gray sand rock; 80-gallon flow; 1-foot layer of pyrites at base	518–558
Sand rock, pinkish	558–589
Calcareous sand rock, pink	589–601
Quartzite, pink, with calcareous beds	601–674
Sioux quartzite	674–680

This record is probably more accurate than some others which have been published, in indicating a thickness of 120 feet of chalk under the drift.

BROOKINGS COUNTY.

Brookings County is in the drainage basin of Big Sioux River, on the east coteau, and ranges in altitude from about 1,600 to 1,800 feet. The region is heavily mantled by glacial drift and underlain by a considerable thickness of Pierre shale. To the south and east the Sioux quartzite appears to rise rapidly, and probably the Dakota sandstone is cut off by it in all of the area east of Volga and south of White. In the area underlain by the Dakota sandstone the altitude of the land is too high for the water to flow.

At Brookings a boring was made several years ago that is said to have reached the quartzite at a depth of about 556 feet. It obtained a small amount of water in overlying sandy beds, probably in the Benton group, but the pressure was not sufficient to afford a flow. A well at Elkston is 230 feet deep, with the last 30 feet in sandstone which is probably at the top of the Benton group.

BROWN COUNTY.

Brown County lies in the James River valley, and consists almost entirely of a level plain traversed by a few shallow depressions carrying the drainage. It is covered with glacial deposits, but from numerous well borings these are known to be underlain by a thick mass of Pierre shale and underlying Niobrara, Benton, and Dakota beds, resting on quartzite and granite. The strata lie very nearly level and the average depth to the top of the Dakota sandstone is between 850 and 1,000 feet. The sandstone contains a great volume of water, yielding large flows, most of which have a pressure considerably more than 100 pounds to the square inch, the amount varying somewhat in different portions of the county. In 1906 it was estimated that there were about 300 artesian wells in active operation in the county.

The depth and other features of these wells are given in the following table:

Artesian wells in Brown County.

Township.	Range.	Depth.	Yield per minute.	Remarks.
		Feet.	*Gallons.*	
121	60	949	57	
121	61	900, 940	14, 43	Pressure 168 pounds.
121	62	930, 960	106, 306	
121	63	898–980	33–96	
121	64	1,000	96	Warner town well.
121	64	903–1,015	35–96	Pressure 20–60 pounds.
121	65	1,070	46	
122	60	940–1,000	15–76	Town of Ferney.
122	61	900–960	39–70	Pressure 125 pounds.
122	63	920–940	25–34	Pressure 120 pounds.
122	64	1,000	30	
122	65	1,080	37	
123	60	920–977	10–105	Pressure 80 pounds.
123	60	922, 960	830	Pressure 135 pounds; Groton town wells Nos. 1 and 2.
123	61	920–935	15–123	
123	62	900	95	
123	63	.....	31–96	
123	64	918–1,117	250, 1,060	Aberdeen town wells. Pressures 40 to 138 pounds. The 1,117-foot well is in T. 123, R. 63.
123	64	1,300	1,350	Aberdeen city well No. 3.
123	64	1,300	1,000	Aberdeen city well No. 4.
123	65	1,070–1,167	25–53	
124	60	885–942	88–150	Pressure in 942-foot well 127 pounds.
124	61	912	.....	
124	62	900	25	
124	63	945	123	
124	64	875–975	15–31	
125	61	716	.....	
125	62	872–1,002	25–940	Largest yield at Columbia, pressure 160 pounds.
125	63	942–983	30–35	
125	64	1,050	.....	
125	65	1,021–1,100	21–48	
126	60	950	248	
126	61	965	.....	Pressure 135 pounds; several flows.
126	64	1,030	.....	Pressure 35 pounds.
126	65	1,073–1,150	17–136	
127	61	960	56	
127	62	900, 940	35, 36	
127	63	800, 856	.....	
127	64	1,094–1,200	10–139	Frederick city well; 139-gallon flow, pressure 70 pounds.
127	65	1,084–1,200	30	
128	60	840	.....	
128	61	920–1,270	20–144	
128	62	975	100	

These wells passed through a great thickness of gray and blue clays, representing the Pierre, Niobrara, and Benton. In the Benton there was generally found a thin bed of sandstone yielding a small amount of first-flow water. The Dakota sandstone is usually overlain by hard cap rock and consists of a succession of soft sandstone layers, with bodies of shale and sandy shale varying in thickness from a few feet to 50 or 60 feet in some wells. All the sandstones contain water, but the volume and pressure usually increase in the lower beds. In the Aberdeen city well No. 4 the base of the formation was found to consist of 49 feet of sand without much water, underlain by quartzite and granite, the top of the granite being entered at a depth of about 1,267 feet.

BRULE COUNTY.

Brule County extends eastward from Missouri River and is in greater part an elevated plateau, or region of gently rolling plains, from 300 to 400 feet higher than the river. In the southern portion the Bijou Hills rise still higher, their altitude probably being somewhat over 2,000 feet. All the highlands are covered by glacial drift lying on Pierre shale. The Bijou Hills are capped by Tertiary sands and green quartzite. Missouri River cuts through the Pierre shale and exposes the Niobrara chalkstone in the lower valley slopes.

The artesian waters of this county have been extensively developed, for more than 60 wells are reported, most of them between 800 and 1,000 feet in depth. Nearly all of them furnish large flows of excellent water, which is used mainly for irrigation. One of the wells near Chamberlain is reported to have a flow of 3,000 gallons per minute. The average flow of a 6-inch well is about 500 gallons, and of a 2-inch well, of which there are many, from 50 to 150 gallons. On the higher lands the pressures are moderate, but in some places rise above 50 pounds per square inch. Wells on the lower lands have greater pressure, one of the city wells in Chamberlain having over 100 pounds and developing 10 horsepower.

The greater part of the water is obtained in the upper part of the Dakota sandstone, but in a region extending through Kimball the upper beds are too compact to yield much water and it is necessary to sink to a looser sandstone below. Artesian waters appear to be available throughout this county, except on the higher portions of the Bijou Hills. The following is a list of wells in Brule County, arranged by townships:

Artesian wells in Brule County.

Township.	Range.	Depth.	Yield per minute.	Remarks.
		Feet.	*Gallons.*	
101	67	750–950	18–60	Pressure 20 to 40 pounds.
101	68	815–962	20–1,098	Pressure 12 to 25 pounds.
102	67	750–880	18–100	Pressure 40 pounds in some wells.
102	68	800–1,050	9–1,000	Pressure in one well 10 pounds.
102	69	900	50–800	Pressure 5 to 40 pounds.
102	70	1,027–1,230	400–900	Pressure 2 to 40 pounds.
102	71	1,230–1,270	45–605	
103	67	840–956	40–90	
103	68	900–1,210	60–750	
		1,254	185	Kimball city wells; original pressure 7 to 20 pounds.
103	69	983–1,210	12–60	Pressure 40 pounds.
103	71	1,063,1,100	25–1,000	
104	68	960	128	
104	69	940–1,200	60–70	
104	70	927	1,385	Flows at 890 and 903 feet.
104	71	600–1,186	3–300	
104	71	645,670	4,500	Chamberlain Electric Co.'s wells Nos. 1 and 2; supply and pressure diminished.
104	71	540–600	1,450–5,000	Quarnberg's four wells; flow decreasing.
104	71	815,960	537,700	Chamberlain city wells Nos. 1 and 2; supply greatly diminished.
105	67	940	80	
105	68	930–987	300–815	Pressure 5 to 75 pounds.
105	69	1,075	30	Flows at 990 and 1,060 feet. Pressure 16 pounds.

Two representative well sections in this county are as follows:

Record of well on Carpenter farm, near Pukwana.

	Feet.
Black loam	0– 60
Yellow sand	60– 72
Blue clay	72–196
Chalk rock	196–435
Black clay	435–536
First sand	536–559
Blue-black clay	559–749
Second sand	749–771
Light chalky clay	771–845
Third sand (Dakota sandstone)	845–907

This well is on high land and the chalk rock is overlain by over 100 feet of Pierre clay.

Record of power well, Chamberlain.

	Feet.
Sand and gravel	0– 22
Blue clay	22– 42
Chalk rock	42–132
Blue clay, tough and dark below	132–498
Sand	498–507
Tough dark clay	507–555
Sand and clay with flow	555–584
Fine dark sand, very fine below	584–612
Hard sand rock	612–619
Compact sandstone	619–633
Sandstone under capstone yielding a flow of 4,350 gallons per minute from an 8-inch pipe	633–689

The chalk rock in this section is in the lower portion of the Niobrara, and the Benton shales appear to extend from 132 to 555 feet in depth.

In its lower part the deep boring at Kimball penetrated very hard, dry sandstones, which, it was thought, might possibly be Sioux quartzite. Samples forwarded by the driller from depths of 1,157, 1,175, 1,190, 1,210, 1,225, 1,240, and 1,246 feet represented hard buff sandstone with considerable oxide of iron in their cement, especially in the 1,246-foot sample. Iron sandstones were also penetrated from 1,130 to 1,138 feet and 1,140 to 1,150 feet; hard, sandy clay from 1,150 to 1,155 feet; buff sandstone at 1,143 feet; and buff clay from 1,153 to 1,170 feet.

BUFFALO COUNTY.[a]

In Buffalo County the geologic conditions are similar to those in Brule County, but the depth to the Dakota sandstone is slightly greater, the strata dipping gently to the northwest and the land rising slightly as the river is ascended. It is probable that the depth

[a] Including part of Crow Creek Indian Reservation.

to the sandstone is about 900 feet at the northwest end of the county in the Missouri Valley and 1,100 to 1,200 feet in the higher lands.

To judge from the pressure observed in wells in this and the surrounding counties artesian flows may be expected throughout the county, except possibly on the very highest summits northwest of Gann. Several wells are reported; one at Crow Creek Agency, another in sec. 1, T. 108, R. 70, and a third on the south branch of Crow Creek below Vega. The last has a depth of 875 feet and a flow of 135 gallons per minute of hard water, with a pressure estimated at 75 pounds. It is a 2-inch well, and the first flow was reported at 800 feet. The well in the SW. ¼ sec. 1, T. 108, R. 70, is said to be 1,450 feet deep and 2 inches in diameter, and has a flow of 27 gallons per minute. The water rises 20 feet or more above the ground.

The well at the Crow Creek Agency was sunk in 1896 by the United States Indian Bureau. It has a depth of about 780 feet and is 6 inches in diameter. The flow is very large, and it is stated that the column of water rises 5 feet above the surface when the well is wide open. The closed pressure exceeded 180 pounds, the total registering capacity of the gauge. With a 1⅝-inch nozzle outlet the remaining pressure is 85 pounds; with a 1⅞-inch nozzle outlet, 70 pounds; and with a 2-inch nozzle, 65 pounds. The temperature of the water is 72° F. and its specific gravity 1.004. The well at first threw out white sand, but this discontinued after a while, and its subsequent behavior has been entirely satisfactory. The first flow was found at 409 feet, but its head was barely sufficient to bring the water above the surface. The final flow was reached at 760 feet, and the water-bearing sand penetrated to a depth of 20 feet. The following record is based on a few samples, with explanatory notes by the agent:

Record of artesian well at Crow Creek Agency, on Missouri River, Buffalo County.

	Feet.
Gravelly beds, some clay	40– 78
Gray clay on thin bed of small gravel	78– 88
Gray shale	88–242
Gray limestone	242–252
Gray chalk, etc., with first flow at 409 feet	252–409
Pyrites	409–435
Shale (?) on 3-foot layer of pyrites	435–700
Shale, with pyrites	700–760
Sandstone, main flow	760–780

BUTTE COUNTY.

Butte County occupies the northwest corner of the State, with an area of over 8,500 square miles, lying mainly on the Great Plains. Its northwest corner is crossed by the Black Hills uplift, exposing formations from the Spearfish red beds upward. The northern, central, and eastern portions of the county are occupied by a consider-

able thickness of Fox Hills and overlying formations, the Dakota sandstone lying more than 2,500 feet below the surface in the lowest valleys. The Fox Hills and overlying sandstones contain local water supplies, which may be available in deep wells, but their capabilities in this respect have not yet been tested.

The greater part of the region lying between Indian Creek and Owl River is underlain by the Pierre shale, and the Dakota sandstone appears to be within reach of deep borings; but to judge from the pressures exhibited in the wells at Belle Fourche, the country is too high for artesian flows. Between Indian Creek and the hogbacks of Dakota sandstone south of Belle Fourche there is a district extending northwest and southeast in which the Dakota sandstone waters are available at depths ranging from slightly more than 300 feet just south of Belle Fourche to about 2,000 feet on Indian Creek, the rate increasing as the formation descends in its dip to the northeast.

Artesian wells and deep borings in Butte County.

	Depth.	Depth to main flow.	Diameter.	Yield per minute.	Pressure.	Remarks.
Belle Fourche city wells:	*Feet.*	*Feet.*	*Inches.*	*Gallons.*	*Pounds.*	
No. 1	550	.....	.....	.....	55	
No. 2	525	525	.....	200	45	
No. 3	881	560	4	30	.....	
Belle Fourche, many small wells.	300–400	.....	1–2	1	.....	First flow; soft.
Belle Fourche, Craft's addition	897	560	.....	45	55	Second flow; small one at 340 feet.
Land and Cattle Company, NW. ¼ sec. 11, T. 8, R. 2.	635	635	1	Many.	55	Second flow; first flow at 450 feet, in valley; hard.
Do	745	680	.....	15	40	Second flow; water also at 450 and 650 feet.
F. A. Durst, NW. ¼ sec. 14, T. 8, R. 2.	550	500	4½	100	26+	
F. N. & G. S. Fuller, NW. ¼ sec. 6, T. 8, R. 3.	835	800	2	30	15	First flow; very soft.
J. A. Gilbert, SE. ¼ sec. 36, T. 9, R. 2.	836	814	2	15	.....	Soft. Some water at 600 feet.
Orman & Crook, SW. ¼ sec. 19, T. 9, R. 4.	1,417	1,325	3–2	60	.....	Flow also at 1,345 feet; temperature, 94°.
H. L. Barnett, SE. ¼ sec. 31, T. 9, R. 3.	935	.....	2	5	.....	First flow; soft.
J. Wichert, SE. ¼ sec. 24, T. 8, R. 2.	381	360+	.....	2	30	First flow; soft; sandstone begins at 280 feet.
Case ranch, SE. ¼ sec. 14, T. 8, R. 2.	241	.....	1¼	2	.....	First flow; very soft.
Do	355	.....	4½	40	26	Soft.
G. H. Ray, SE. ¼ sec. 12, T. 8, R. 2.	818	760	2	5	.....	Water also at 500 feet; hard.
U. S. Reclamation Service, SE. ¼ sec. 36, T. 9, R. 2.	627	625	2	20	.....	First flow at 567 feet; shale between.
U. S. Reclamation Service, SE. ¼ sec. 18, T. 9, R. 4.	1,388	1,380	2	1	9+	
Newland ranch, SW. ¼ sec. 4, T. 8, R. 3.	1,033	1,013	2	15	15	
Brant's road ranch, SE. ¼ sec. 23, T. 10, R. 2.	2,019	.....	.....	.....	Flows.	
Fred Ross, NW. ¼ sec. 4, T. 9, R. 4.	1,858	1,783	1¼	3½	.....	First flow; soft.
M. Snyder, SE. ¼ sec. 13, T. 8, R. 4.	1,096½	1,080	2	60	Flows.	First flow; soft but irony.
J. A. Scotney, NE. ¼ sec. 20, T. 8, R. 2.	330	.....	4	25	30	
Do	225	.....	6	15	.....	Hard.
S. Johnson, SW. ¼ sec. 13, T. 8, R. 2.	330	.....	.....	.....	15	
W. R. Glassie, NE. ¼ sec. 28, T. 8, R. 2.	320	.....	.....	.....	5	Second flow.
D. Richardson, Hay Creek, 6 miles west of Belle Fourche.	220	.....	4	25	.....	Water rises 9 inches above pipe.

Artesian wells and deep borings in Butte County—Continued.

	Depth.	Depth to main flow.	Diameter.	Yield per minute.	Pressure.	Remarks.
	Feet.	*Feet.*	*Inches.*	*Gallons.*	*Pounds.*	
T. Rawlins, SW. ¼ NE. ¼ sec. 17, T. 8, R. 2.	535	515	3	5	10+	First flow at 330 feet.
H. M. Stearns, SE. ¼ NW. ¼ sec. 13, T. 8, R. 3.	600	.....	.....	450	125	
Schaffer ranch, SW. ¼ sec. 14, T. 9, R. 2.	900	.....	.....	.....	.....	In progress; in shale.
R. D. Evans, sec. 6, T. 8, R. 2.	900	470	3	15	20	Soft. Water also at 274 feet.
William Barbour, NE. ¼ sec. 35, T. 9, R. 1.	350+	.....	4	Many.	.....	
J. Chambers, SE. ¼ sec. 17, T. 8, R. 1.	280	180	.....	.....	.....	Hard water to −9 feet; abandoned.
J. Chambers, NE. ¼ sec. 20, T. 8, R. 1.	356	310	4½	1½	.....	Do.
J. Chambers, NW. ¼ sec. 8, T. 8, R. 1.	700	.....	.....	.....	.....	Water rises to −100 feet; into red beds 15 feet; abandoned.
H. Wittenbaugh, NE. ¼ sec. 9, T. 9, R. 7.	460	.....	6	.....	.....	Failure.
Vale	2,215	.....	.....	.....	.....	In progress March, 1909.

Belle Fourche and vicinity.—Since 1904 the village of Belle Fourche has been supplied by water from artesian wells which penetrate the Dakota or underlying sandstones. The deeper wells have sufficient pressure to flow into a tank 75 feet high, on a knoll just south of the railroad depot. Shallower wells afford supplies at various residences. The first well had a depth of 525½ feet, flowed 60 gallons a minute, and originally had a pressure of considerably more than 55 pounds to the square inch. It finally got out of order, apparently owing to a break in the casing, and other wells were sunk which obtained additional supplies. The materials penetrated in the first well were as follows: Shales, 207 feet; sandstone (Dakota), 100 feet, yielding a small flow at a depth of 245 feet; soft clay (Fuson), 118 feet, containing a thin layer of sand yielding a small second flow; and sandstone (Lakota), 100 feet. The Lakota sandstone contained water at various horizons with gradually increasing volume and head, the maximum flow being at about 510 feet in the lower part of the formation. The second well, on somewhat lower land near the center of the village, had the following record:

Record of second well at Belle Fourche.

	Feet.
Shale	0–300
Hard sandstone, small flow	300–330
Soft sandstone with flow at 410 feet (Dakota sandstone)	330–410
Red, white, and mottled clay (Fuson formation)	410–435
Gray sandy clay and sandstone with lignite fragments (Lakota)	435–470
Sandstone	470–525

A pressure of 45 pounds is reported in this well.

A third well, bored in 1903 to a depth of 881 feet, found water-bearing strata at intervals from 297 to 560 feet. The well is 4 inches in diameter and has a flow of 30 gallons a minute. Several small wells in the village are supplied by the first flow at depths of 300 to 400 feet.

A well in Craft's addition, three-fourths of a mile east and one-fourth mile south of well No. 1, is 560 feet deep to the second flow, with a pressure of 55 pounds. This well was drilled to 897 feet with no increase of water below 560 feet.

There are two artesian wells on property of the Belle Fourche Land and Cattle Company in the NE. ¼ NW. ¼ sec. 11, T. 8 N., R. 2 E., a mile north of the village. The first, which was sunk in 1904 has a depth of 650 feet. It draws from the second flow, at 635 feet. The water is somewhat hard and the pressure is 55 pounds. A first flow, of softer water, was found at a depth of 450 feet. The following record is given:

Record of artesian well 1 mile north of Belle Fourche.

	Feet.
Shale	0–350
Sandstone (Dakota)	350–450
Shale and clay (Fuson)	450–550
Sandstone (Lakota)	550–650

A second well, on a small knoll north of the river in the northwest quarter of the same quarter section, has a depth of 744 feet. It yields a 15-gallon flow of soft water under pressure of 40 pounds. A small flow was found at a depth of 650 feet in this well.

F. Durst has a well in the NE. ¼ NW. ¼ sec. 14, T. 8 N., R. 2 E., on a hill about 70 feet above Belle Fourche. It was sunk in 1906, has a diameter of 4½ inches and a depth of 550 feet, and found the main flow at 500 feet and minor flows at 350 and 400 feet. The pressure is sufficient to raise the water 60 feet. The volume is 100 gallons a minute and the quality fairly soft. The following record is supplied by the driller:

Record of Durst artesian well south of Belle Fourche.

	Feet.
Sand and gravel	0– 20
Black shale	20–220
Gray shale	220–320
Sandstone	320–332
Shale	332–422
Clay and shale	422–442
Hard close sandstone; no water	442–492
Soft white sandstone; much water	492–550

Two wells on the Case ranch, a mile farther south, have depths of 241 and 355 feet and yield good flows of soft water. The deeper well shows a pressure of 26 pounds.

Another shallow well just south of Minnesela, with a depth of 381 feet, has a 2-gallon flow of soft water under a pressure of 30 pounds.

United States Reclamation Service wells.—The United States Reclamation Service has drilled two artesian wells in connection with the Belle Fourche project, one at the dam site on Owl Creek, in the SE. ¼ SE. ¼ sec. 18, T. 9 N., R. 4 E., and the other at the intake of the diversion canal 1½ miles below Belle Fourche. The well at the dam site

is 1,380 feet deep, and has a 1-gallon flow under pressure sufficient to raise the water 20 feet or more. The boring was in Carlile and Granceros shales, with hard streaks at 250, 540, 640, 790, 900, and 1,330 feet, that at 250 feet probably representing a portion of the Greenhorn limestone. The Dakota sandstone was entered near the bottom; so the well is supplied by the first flow.

The well at the intake of the diversion canal is on the north bank of Belle Fourche River, in the SE. ¼ sec. 36, T. 9 N., R. 2 E. It is 627 feet deep and 2 inches in diameter, and obtains its supply from a depth of 625 feet. A first flow was found in the Dakota sandstone at a depth of 567 feet. Shale (Fuson) separates the two flows. The following is an analysis of the water:

Analysis of water from artesian well at intake 1½ miles below Belle Fourche.

[By F. M. Eaton.]	Parts per 100,000.
Ca	0.97
Mg	.24
Na	15.37
SO	14.09
Cl	1.62
HCO_3	22.20
CO_3	1.59
N as NO_3	.001

Orman well.—The Orman well is situated in the NE. ¼ SW. ¼ sec. 19, T. 9 N., R. 4 E., at the south end of the Owl Creek dam. It was finished in October, 1906. The diameter is 3 inches and the depth 1,417 feet. The water-bearing bed was entered at a depth of 1,325 feet and is a very coarse sandstone 40 feet thick. The flow at an altitude of 3,017 feet, or 18 feet above the ground, is 50 gallons a minute, and 26 feet higher it is 32 gallons. The temperature is 94°. Another well 6 inches in diameter is now being drilled on ground 45 feet higher a few rods farther south, and in May, 1907, it had reached a depth of 1,100 feet. An analysis of the water from the 3-inch well is as follows:

Analysis of water from well at Orman.

[By W. A. Converse.]	Grains per gallon.
Silica	0.75
Oxides of iron and alumina	.16
Calcium sulphate	36.18
Magnesium carbonate	10.05
Magnesium sulphate	2.00
Sodium and potassium sulphates	15.20
Sodium and potassium chlorides	.34
Loss, etc	.03
Total solids	64.11

Free ammonia, 0.02; albuminoid ammonia, 0.01 part per million. No nitrogen as nitrates or nitrites. Chlorine as chlorides, 3.54; oxygen consumed, 3.50 parts per million.

Chambers ranch.—On the Chambers ranch, in the SW. ¼ NW. ¼ sec. 8, T. 8 N., R. 1 E., on the hogback ridge 9 miles west of Belle Fourche, a boring was sunk in 1899 to a depth of 700 feet. It obtained no flow and was finally abandoned. The following record is given:

Record of boring on Chambers ranch 9 miles west of Belle Fourche.

	Feet.
Soil	0– 10
Sandstone and clay; water rising to —100 feet at 180 feet	10–300
Clay, some sandstone	300–490
Reddish sandstone	490–540
Water rising to —100 feet in gray sandstone	540
Green shale and clay (basal Sundance)	540–580
Red sandstone	580–685
Red beds under hard ironstone layer	685–700

The boring began at the top of the Dakota sandstone and penetrated that formation and the underlying Fuson and Lakota beds within the first 200 feet. The water at a depth of 180 feet was in the Lakota sandstone, which affords the large flows in the valleys about Belle Fourche, but the boring was on land over 100 feet too high for a flow. The reddish sandstone at a depth of 490 to 540 feet was in the Sundance formation, and the water at 540 feet was in the sandstone near the lower portion of the Sundance. The Spearfish red beds were entered at a depth of 580 feet and penetrated for 120 feet.

Vale.—In March, 1909, Mr. H. H. Stearns reached a depth of 2,215 feet with a boring for gas. Near the bottom Dakota sandstone was penetrated, underlain by a thin coal layer, 25 feet of soapstone, and 15 feet of white and blue mud and red chalky clay.

CAMPBELL COUNTY.

Campbell County lies mainly on the high plateau on the east side of the Missouri Valley, but it extends to Missouri River, along which it includes a narrow belt of lower lands. The higher ridges are underlain by thick deposits of glacial drift lying on a thick mass of Pierre shale, but in some of the higher areas thin deposits of sandy beds intervene. The shales outcrop extensively along the river bank. The county is undoubtedly underlain by the Dakota sandstone at depths ranging from 1,400 feet in the southwest corner of the county to 2,000 feet or more in the higher portions. No wells are reported in this county, but the records of wells in adjoining counties indicate that flows may be expected up to an altitude of about 1,900 feet.

CHARLES MIX COUNTY.

Charles Mix County extends along the east bank of the Missouri River for 75 miles or more and onto the high plains to the northeast. These plains are elevated about 300 feet above the river and have some ridges upon them which rise considerably higher. The high lands are covered by drift, but along the river banks and in some of the valleys the Niobrara chalkstone appears, overlain by Pierre shale. The Dakota sandstone underlies the county and is the source of water in numerous wells. Artesian flows are available in all but the very highest lands, there being one small nonflowing area west of Geddes and another on the morainal hills south of Wagner; possibly there are a few other localities too high for flows. Wells are most numerous on the plains in the northern townships; others are sunk at intervals along the river bottom and in some of the southeastern townships. The following nearly complete list includes all wells from which returns have been received:

Artesian wells in Charles Mix County.

Township.	Range.	Depth.	Average yield per minute.	Remarks.
		Feet.	*Gallons.*	
94	64	651	3,000	Pressure 119 pounds.
95	63	795	.....	
95	64	1,020	.....	Sec. 15; no flow.
95	65	730	16	pressure 40 pounds.
96	62	150	.....	
96	63	151	8–15	
96	64	144	7½	
96	65	775½, 802	1,500	Pressure 70 pounds.
96	67	266	.....	Pressure 10+ pounds.
96	68	810	37	
97	63	150	.....	
97	66	800–905	4–20	
97	67	700–900	5–150	Pressure 5 pounds.
98	64	772	200	Pressure 52 pounds.
98	65	920–940	6, 11	Pressure 2 to 8 pounds.
98	66	820–950	50–65	Pressure 24 to 30 pounds.
98	67	800–991	6–65	Various pressures are reported, the greatest being 63 pounds.
98	68	800–1,110	10–150	Pressure 3 to 80 pounds.
98	68	1,220	.....	Sec. 14; no flow.
98	69	644	50	Pressure 24+ pounds.
99	66	840	20	Do.
99	67	730–950	4–50	Greatest pressure reported, 50 pounds.
99	68	720–1,006	2–78	Greatest pressure reported, 40 pounds.
99	69	944, 966	60	Pressure, 50 pounds.
99	70	840–1,000	10–30	Pressures 20 to 26 pounds.
100	67	734–875	20–120	Greatest pressure reported, 87 pounds.
100	68	720–930	7–31½	Greatest pressure reported, 13 pounds.
100	69	856–1,030	15–125	Pressure in one well, 15 pounds.
100	70	890, 900	16	Pressure 30 pounds.
100	71	688–868	500–2,352	

The materials penetrated in wells in this county vary considerably. On the higher lands they consist of more or less drift and Pierre shale, underlain by chalk rock, and this in turn by the Benton group, with layers of sandstone and limestone. The Dakota sandstone is usually entered for some distance to obtain a sufficiently large volume of

water and on the higher lands for increased pressure. The following is the record of well No. 2, sunk by the Government at Lake Andes:

Record of well No. 2 at Lake Andes, Charles Mix County.

	Feet.
Yellow gravelly clay	0– 20
Blue clay and hardpan	20– 45
Sand and gravel	45– 55
Blue bowlder clay	55–130
Sand and gravel	130–163
Black shale (Pierre?)	163–180
Blue shale, with lime	180–265
Lime rock (chalk?)	265–280
Yellow sandy shale	280–335
Gray shale	335–475
Blue shale, with lime	475–520
Shelly lime rock	520–550
Blue shale	550–615
Sandstone, light color	616–623
Blue shale, with sand and pyrites	623–725
Sandstone, light color	725–773
Soapstone	773–775½

The sandy beds that lie a short distance below the supposed chalk probably represent the sandstone member which is persistent under a wide area in southeastern South Dakota. The layers of lime rock which extend from 520 to 550 feet represent the Greenhorn limestone horizon in the Benton group. The precise boundary between the Benton and Dakota is difficult to discern in the record as given, but probably it is at a depth of 725 feet, the sandstone extending from this depth to 773 feet and yielding a 1,500-gallon flow of water.

The following record is given for the well at the Yankton Agency:

Record of well at Yankton Agency, Greenwood, Charles Mix County.

	Feet.
Soil	0– 1
Yellow sandy clay	1– 25
Gray shale	25– 41
Blue shale	41– 75
Blue shale, with chalk and gravel	75– 91
Yellow sand and gravel	91–114
Gray rock	114–117
Gray shale	117–123
Gray limestone and pyrites	123–144
Sandy shale and sand	144–178
Much water, which rises to —65 feet	144–178
Blue shale	178–199
Black shale, with pyrites and shells	199–275
Blue shale, tough	275–380
Black shale, with pyrites and shells	380–420

	Feet.
Sand with flow of 10 gallons per hour; temperature 56°	420–421
Brown shale, with streaks of sand and lime rock	421–448
Black shale, with thin sandy streak; flow, 7 gallons per minute at 482–485 feet; soft water	448–497
Gray shale	497–500
Black shale, with lime and pyrite streaks	500–531
Gray shale	531–552
Sandstone; third flow, 15 gallons per minute	552–556
Gray shale	556–577
Sandstone; fourth flow, 30 gallons per minute; soft water	577–579
Gray shale full of lime and pyrite streaks 2 to 12 inches thick	579–641
Sandstone, very soft; 3,000-gallon flow, hard water; temperature 70°	641–651

CHEYENNE INDIAN RESERVATION.

The Cheyenne Indian Reservation lies in north-central South Dakota, north of Cheyenne River, between Missouri River and longitude 102°. It comprises the deep valleys of Cheyenne, Missouri, and Owl rivers, together with Fox Ridge and the range of high hills north of Owl River, thus covering a region having considerable diversity of topography and a range of more than a thousand feet in altitude. The high ridges are capped by Fox Hills sandstone and to the west by the overlying lignitic formation; the valleys are excavated deeply in Pierre shale. This shale has a thickness of about 1,000 feet, as nearly as could be ascertained, and is underlain by a regular succession of Niobrara and Benton shales and Dakota sandstone. The Dakota has been reached at the Cheyenne Agency at a depth of 1,317 feet and found to contain a large volume of water—500 gallons per minute—under a pressure of 205 pounds to the square inch. As the mouth of the well is at an altitude of about 1,500 feet above sea level, the pressure indicates a head of 1,970 feet—sufficient to afford a flow far up the slopes of the high ridges in the central and northern parts of the reservation and throughout the valleys. As the hydraulic gradient rises to the west toward the Black Hills, the altitude at which flows are obtainable and the pressures in the lowlands both gradually increase also in that direction.

Owing to the slight westerly dip of the formations and the rise in the land the Dakota sandstone doubtless lies much deeper in the western portion of the reservation than at Cheyenne Agency. On Cheyenne River, at the west border of the reservation, its depth is probably nearly 2,000 feet. On Owl River, which is in a somewhat higher valley, it is estimated to be at a depth of at least 2,200 feet.

The well at the Cheyenne Agency is in the Missouri Valley, on a terrace about 40 feet above the river. The flow was found at a

depth of 1,317 feet, under a cap rock 1 foot thick. The pressure when the well was first closed was 187 pounds, but the amount increased to a maximum of 205 pounds in four days. The well contains 530 feet of 8-inch casing, 1,015 feet of 6-inch casing, and 1,337 feet of 4-inch casing. The water has a temperature of 79° or 80°, is similar in salinity to that at Pierre, and also contains much illuminating gas, which was encountered by the 8-inch casing and amounts to about 3,400 cubic feet per day. The log of the boring, kindly furnished by A. E. Swan, is as follows:

Record of artesian well at Cheyenne Agency, Cheyenne Indian Reservation.

	Feet.
Yellowish gravelly clay	0– 21
Sand bowlders, and shale fragments	21– 26
Shale, hard	26– 40
Blue shale, firm	40– 280
Blue shale, soft	280– 390
Black shale	390– 485
Sandy shale	485– 500
Gray shale	500– 515
Hard shale	515– 575
Dark-gray shale; gas at 650 feet	575– 700
Black shale, with some beds of hard sandstone	700–1,050
Blue shale	1,050–1,200
Dark-gray shale; gas	1,200–1,311
Yellow lime rock, soft	1,311–1,317
White sandstone; flow	1,317–1,323
Brownish shale	1,323–1,337

Although the water of this well is somewhat saline, the boring is to be regarded as a great success. The pressure is phenomenal and could, if necessary, be utilized for running a large amount of machinery.

CLARK COUNTY.

Clark County extends from the east margin of the James River plain far up the western slope of the east coteau, having a range in altitude from about 1,400 feet to 1,800 feet.

Raymond.—The first flowing well bored in the county was on the farm of Bohri Brothers, in the SE. ¼ sec. 22, T. 117 N., R. 59 E., about 1½ miles northeast of Raymond, at an altitude of about 1,490 feet. The total depth of the boring was 1,200 feet, but the casing extended only to 1,075 feet. The diameter of the casing was 6 inches, and the lower 40 feet were perforated. Flows were found in sands from 1,005 to 1,025 feet and from 1,050 to 1,053 feet. The well was finished in the spring of 1892, and the water continued to flow with a closed pressure of 80 pounds until the winter of 1893, when the

casing became clogged up and the flow diminished to a small drip. The log of the boring is as follows:

Record of well 1½ miles northeast of Raymond.

	Feet.
Yellow clay	0– 37
Blue clay	37– 66
Sand, gravel, and clay	66– 80
Sand, clay, and gravel	80– 100
Hardpan	100– 126
Gray shale	126– 184
Blue shale	184– 194
Slate	194– 199
Blue shale	199– 279
Gray shale	279– 344
Blue shale	344– 434
Dark-brown shale	434– 524
Blue shale, with thin layer of sand rock and shale	524–1,005
Sand rock, with flow	1,005–1,025
Lime rock, with thin layer of sand containing small flow	1,025–1,053
Shale	1,053–1,143
Green shale (rock layers)	1,143–1,198
Hard rock	1,200

The water-bearing bed is in the top of the Dakota sandstone, and probably is the same as the one which supplies the Doland, Andover, Conde, Groton, Turton, and many other wells. This flow is obtainable all along the western margin of the county up to altitudes of 1,600 feet.

Several wells near Raymond obtain flows at 1,013 to 1,075 feet, and several in the southwest corner of the county, averaging from 1,000 to 1,040 feet, have moderately large flows under considerable pressure.

Clark.—Two attempts have been made to obtain the artesian waters at the village of Clark, but in both the tools were lost at a depth of about 1,200 feet and the borings were abandoned. The water-bearing beds probably lie at a depth of about 1,300 feet at Clark, but the head is not sufficient for a surface flow at that locality. No doubt a well to this depth would obtain a large volume of water which would rise within about 110 feet of the surface and afford very satisfactory force-pump wells.

CLAY COUNTY.

Clay County lies in the valleys of James and Missouri rivers near the southeast corner of South Dakota. Its surface is mostly covered by glacial and alluvial deposits, but the underlying formations—Niobrara chalkstone in the higher lands and Benton shales in the lower valleys to the south—appear here and there. The Dakota

sandstone lies at a moderate depth below the surface—600 feet in the northwest corner of the county and about 200 feet in its southeast corner, the beds rising gradually to the southeast.

The sandstone contains water throughout the county, but, owing to the diminution of head toward the southeast, flows are obtainable only in the lower lands. The flow area comprises the southwest quarter of the county, the valley of Vermilion River and its larger branches, and the lowest lands of the Missouri Valley below the mouth of Vermilion River. In this area there are many flowing wells, mostly from 250 to 500 feet in depth, which yield large supplies of excellent water. Most of the wells are small and many obtain their water from the top of the Dakota sandstone. Some first flows are also obtained from sandstone near the bottom of the Benton group. The following is a list of the wells in Clay County:

Artesian wells in Clay County.

Township.	Range.	Depth.	Yield per minute.	Remarks.
		Feet.	*Gallons.*	
91	51	210–280	6 – 20	
92	51	300–400	6 – 90	Water usually rises a few feet above the surface.
92	52	289–507	2 –200	Water rises 20 feet above some wells.
92	53	205–367	2 – 25	Some chalk penetrated. One 35-pound and one 20-pound pressure reported.
93	51	312–410	1 – 20	Pressure in one well 4 pounds.
93	52	243–400	4 – 20	Pressure 15 pounds.
93	53	240–367	1½–150	Pressure 6 to 40 pounds; one well contains alkaline water.
94	52	400	1½	
		402	5	
94	53	260–500	Few.	Some irony water.
95	52	260–507	1 – 3	Alkaline water in one well; pressure 8 pounds.

CODINGTON COUNTY.

Codington County is on the summit of the east coteau, at an elevation varying from 1,700 to over 1,900 feet. At the surface is a thick mass of glacial drift lying on many hundred feet of Pierre shale. The county is underlain by Dakota sandstone, which is doubtless water bearing, but has a head only sufficient to cause the water to rise to about 1,650 feet above sea level, so that no flows are to be expected. The sandstone lies at a depth of about 1,100 feet at Watertown and correspondingly deeper in the highlands of the surrounding hills; as it slopes downward to the west it lies deeper in that direction also.

CUSTER COUNTY.

All the rocks from the Algonkian granites and schists to the Pierre shale and White River group outcrop within Custer County, which extends across the greater part of the Black Hills uplift and eastward to Cheyenne River. There are many running streams

in the higher lands within its borders, but in the lower regions to the east and southwest increased water supplies are greatly needed. On the east side of the crystalline-rock area the formations dip steeply to the east and pass beneath the surface in rapid succession, the Dakota and associated sandstones reaching a depth of 2,600 feet under the higher lands in the eastern part of the county. The top of the Dakota sandstone reaches a depth of 500 feet within about a mile from the foot of the hogback range and descends at about the same rate for the next 5 miles. Farther east the dip gradually diminishes, until in the extreme eastern part of the county the beds lie nearly level. At Hermosa the depth to the top of the sandstone is probably not more than 600 feet; at Fairburn it is about 900 feet. Along the lower portions of Spring, Battle, and French creeks the Dakota sandstone probably lies at about 2,300 to 2,500 feet below the surface, and correspondingly deeper in the higher lands of the intervening divides. Along Cheyenne River the depth probably averages from 2,200 to 2,400 feet. These calculations are based on estimates of the thickness of the Benton group (about 1,300 feet) and of the Niobrara formation (about 200 feet), and on the occurrence of the tepee butte zone in the Pierre shale, apparently at a horizon of about 1,000 feet above the base of that formation. It is probable that flowing water could be obtained throughout the lower lands east of the hogback range, but not on the divides. In the southwest corner of the county a small area underlain by Dakota sandstone may be expected to yield flowing wells, as indicated by the 550-foot flowing well at Argentine, in the adjoining county to the south.

It is possible that underground waters may be found under the Red Valley in this county, in the Minnelusa sandstone or in the underlying Pahasapa limestone and Deadwood sandstone. These formations have not yet been explored for water in this district, but may prove to be important sources of supply here, as at Cambria, Wyo., a short distance northwest. The unsatisfactory results of the boring at Minnekahta Junction are discouraging as to the prospects for water in these formations to the southeast, although that boring did not test the question conclusively, as it apparently did not reach the Deadwood sandstone. It is thought that this sandstone lies at a depth of about 1,000 feet along the center of the Red Valley, the amount slightly increasing toward the hogback range and decreasing toward the Minnekahta limestone outcrop.

At Buffalo Gap two attempts were made to reach the Dakota sandstone. Both borings were slightly more than 700 feet in depth, entirely in the Benton shale. One was on the crest of a low ridge in

the western part of the town, and the other was on the lower land on the main street. As the latter began in the middle of the Carlile shale, it would probably have reached the Dakota sandstone within the next 500 feet and have obtained a flow, although the altitude of the surface is just about at the limit to which the water should be expected to rise in this vicinity.

DAVISON COUNTY.

Davison County lies entirely in the James River valley, near the eastern margin of the Dakota artesian basin. Owing to the uplift of the formations the water-bearing beds are near the surface in a portion of the county, and the waters have been extensively developed by many wells, mostly of moderate depth. In the region south of Mitchell the underground ridge of Sioux quartzite has considerable prominence, its slopes intercepting the Dakota sandstone, so that in several townships the waters from the latter are not available. This is the case south and southwest of Mitchell for several miles, although in a portion of the area sandstones in the Benton group overlap the quartzite and yield flowing wells, in which, however, the pressure is sufficient to afford flow only in the lower lands. Several wells in this district have been bored to the "bed rock," and although some of them have obtained water, they have not had sufficient head to afford a flow. In the northern, western, and southern portions of the county there are wells in nearly every section, most of which find water supplies at less than 500 feet below the surface. Some obtain flows from the sandstone underlying the chalk, others from sandstones low in the Benton group, but most of them have penetrated to the top of the Dakota sandstone. In the southwest corner of the county the land rises considerably and the sandstone dips toward the southeast, so that the depth to the Dakota water rapidly increases. In the extreme southwestern portion of the county the depth of this horizon is between 750 and 800 feet below the surface, and in the valley of Enemy Creek between 350 and 450 feet. About Mount Vernon many wells obtain water, apparently from the Dakota sandstone, at depths from 300 to 420 feet in greater part, most of them also finding upper flows in sandstones of the Benton group. Half way between Mount Vernon and Mitchell there is an area of considerable size in which the Dakota sandstone reaches its maximum uplift and affords flows in wells from 250 to 300 feet deep. On Firesteel Creek and along James River the sandstone is also reached by wells from 200 to 300 feet in depth. In the northern portion of the county the Dakota sandstone dips to the north and the depths increase, but only to 460 feet in the

extreme northwest corner. The following is a list of the principal borings in the different townships of Davison County:

Artesian wells in Davison County.

Township.	Range.	Depth.	Average yield per minute.	Remarks.
		Feet.	*Gallons.*	
101	60	315–525	10–45	Deepest wells are in southwest corner of township.
101	61	395–640	.....	Depths increase regularly from northeast to southwest in this township.
101	62	480–775	60	
102	60	195, 360	No flow.	Flowing water only in southwest corner of township.
102	61	250–500	.....	
		250–375	.....	To "bed rock;" no flow in western part of township.
102	62	350–535	.....	Depth increases gradually southwest of Enemy Creek; a 280-foot well reached bed rock in southeast corner of township (no flow).
103	60	330–550	.....	
103	60	765	.....	In Mitchell flows at 285, 376, 445, and 540 feet; quartzite at 540–765 feet.
103	60	433–586	20–600	In Mitchell and vicinity; pressure 13 to 28 pounds.
103	60	294	.....	Southwest of Mitchell; quartzite; no flow.
103	61	250–375	.....	
		300, 425	.....	Wells to bed rock in southeast corner of township; no flow.
103	62	315–495	.....	Depths gradually increase to southwest.
		646	700	Flows at 350, 470, and 620 feet.
104	60	237–507	10–100	Water beds rise to the east; some water also in sandstone of the Benton.
104	61	260–415	.....	Most wells have also flow from sandstone in the Benton.
		585–653	Many.	Deep into Dakota sandstone; several flows (235, 480, and 585 feet).
104	62	300–601	.....	Depths increase northwestward; many wells have also first flow from sandstone in the Benton.

DAY COUNTY.

Day County lies mainly on the high coteau, but extends westward to the plain of the James River valley. The coteau consists of a high ridge of glacial deposits underlain by a great thickness of Pierre shale. The Dakota sandstone underlies the entire county, having a depth of about a thousand feet at Andover, but being very much deeper under the highlands to the east. It appears to dip gently to the west, judging from its difference in altitude in the well at Milbank and at other places in the James River valley. The formation is undoubtedly water bearing throughout, but as the maximum head of the water is only about 1,680 feet and the land on the summit of the coteau has an elevation of 1,750 to 1,900 feet, flowing wells are not obtainable far east of Andover. There are several successful wells in the vicinity of Pierpoint and at Andover; but on the coteau at Webster, although the Dakota sandstone appears to have been reached, the altitude is too great to afford a flow. A list of the artesian wells in the county follows:

ARTESIAN WELL ON FRAZIER RANCH, 10 MILES NORTHWEST OF MITCHELL, S. DAK.

295 feet deep.

Artesian wells in Day County.

	Depth.	Diameter.	Average yield per minute.	Remarks.
	Feet.	*Inches.*	*Gallons.*	
Webster	1,550	2	.....	Unsuccessful.
John Marso, T. 122, R. 59	1,080	1¼	40	Pressure 85 pounds.
Pierpoint station, T. 123, R. 58	1,240	3	.....	
T. 123, R. 58, northeast of Pierpoint	1,240	.....	.....	Water just flows.
J. C. McConnell, sec. 6, T. 124, R. 58	930	1¼	28	Pressure 70 pounds.
T. P. & W. H. Lemmon, T. 124, R. 58	1,200	1¼	15	Pressure 40 pounds.
Thomas Burridge, sec. 2, T. 124, R. 59	930	1¼	40	Pressure 75 pounds.
V. R. Potter, sec. 36, T. 124, R. 59	970	1¼	35	Pressure 90 pounds.

Andover.—The well at Andover has a flow of 300 gallons per minute, a pressure of 90 pounds to the square inch, and a bore of 6½ inches. Its log is as follows:

Record of well at Andover.

	Feet.
Soil, sand, and clay	0– 50
Blue clay	50– 75
Blue shale	75– 575
Limestone	575– 590
Shale with streaks of limestone	590–1,070
Sandstone with water	1,070–1,075

The water contains 150 grains per gallon of saline ingredients, of which 20 grains are chloride of sodium.

Pierpoint.—The Potter well, 2 miles west of Pierpoint, has a depth of 970 feet, a diameter of 1¼ inches, a flow of 35 gallons per minute, and a pressure of 90 pounds to the square inch. The Lemmon well, a short distance east of the village, has a depth of 1,200 feet, a diameter of 1¼ inches, and a 15-gallon flow under 93 pounds pressure. The first flow is at 1,070 feet.

Webster.—It is claimed by some that the boring at Webster reached a depth of 1,550 feet, but others assert that only 1,400 feet was attained. It is also claimed that a small flow was found at 1,100 feet in 1896. It is improbable that this flow was derived from the Dakota sandstone, for that would indicate a head of 1,840 feet, an amount very much greater than the head in the wells in the James River valley to the west and at Milbank to the east. It is reported that the principal formation underlying the drift was shale, with some beds of pyrites, limestone, and sandstone, and it is also stated that the well penetrated sand supposed to be the Dakota sandstone, which yielded a large amount of water that did not rise to the surface. Some samples of borings submitted are mainly fine sand, but as they are evidently washings from the drillings and no statement is furnished as to their thickness, they throw no light on the stratigraphy.

DEUEL COUNTY.

Deuel County lies on the east side of the east coteau, embracing the ridge which lies between Sioux and Minnesota rivers. The altitudes are about 1,600 feet in the southeast corner, 1,800 feet in the center, and 1,300 feet in the northeast corner. The highlands are mantled by glacial drift lying on a thick mass of Pierre shale. The Dakota sandstone underlies the entire county at depths of 500 to 1,200 feet, being nearest the surface in the lowest land in the northeast corner of the county. The formation probably contains water having a head from 1,400 to 1,500 feet, which would yield a flow in the extreme northeast corner of the county. So far as known, no wells have been sunk to test the conditions of the deeper seated underground waters.

DOUGLAS COUNTY.

Douglas County is on the highlands between the valleys of James and Missouri rivers. It is covered thickly by drift, which is underlain by several hundred feet of Pierre shale. This formation is penetrated by wells which also pass through the Niobrara chalkstone and the Benton shales and sandstones to reach the Dakota sandstone. The latter lies nearly level or has a slight dip to the southeast, but owing to the irregular topography its depth varies considerably.

Most of the wells are between 750 and 1,000 feet in depth and obtain abundant supplies of excellent water, under pressure sufficient to indicate that flows are obtainable in all parts of the county, unless possibly on some of the very highest points in the northwestern and northeastern townships. In the following list are given facts relating to all the wells in this county from which returns have been received:

Artesian wells in Douglas County.

	Depth.	Diameter.	Average yield per minute.	Remarks.
	Feet.	*Inches.*	*Gallons.*	
Delmont	821	2	60	
City of Armour	757	6	1,500	Pressure 55 pounds.
O. H. Bush, sec. 20, T. 98, R. 63	722	1¼	Many.	Pressure 64 pounds.
Armour Mill Co	800	8	1,500	
L. W. Wheelock, sec. 2, T. 98, R. 64	901	8–6	1,200	
Jno. J. Walsh, sec. 24, T. 98, R. 64	736	2	20+	
C. O. Knapp, sec. 2, T. 98, R. 65	860	6	900	
J. A. Wilson, sec. 35, T. 99, R. 63	703½	8–6	2,100	Pressure 75 pounds.
County well, sec. 14, T. 99, R. 65	925	4	600–700	
F. E. Van Zee, T. 99, R. 65	1,010	6	1,000	
Ernest Bertram, sec. 16, T. 100, R. 62	600	2	Many.	
County well, sec. 18, T. 100, R. 62	1,025	.....	1,025	
Flensburg	611	2	60	
Flensburg, ½ mile west	651	2	.....	
Flensburg, ¾ mile west	775	2	65–70	
County well, sec. 15, T. 100, R. 63	750	4	600–700	
County well, sec. 26, T. 100, R. 64	937	6	900	Pressure 40 pounds.
Do	975	4	1,000	
J. Markin, sec. 9, T. 100, R. 65	80	12	Few.	In glacial drift.

Most of the wells appear to draw their supplies from the upper portion of the Dakota sandstone, but others go deeply into it so as to gain additional pressure and volume. The sandstone appears to be 150 feet or more in thickness, lying mostly in one body, but locally there are intercalated masses of shale. It is reported that at the county well in sec. 26, T. 100 N., R. 64 E., the sandstone was entered at 800 feet and was found to be underlain by granite at 937 feet. For the first 60 to 140 feet the wells pass through drift deposits, then through 100 to 200 feet of Pierre shale and 50 to 80 feet of chalk into a bed of the upper sandstone of the Carlile shale which persists over a wide area and yields water to several pumped wells 300 to 450 feet deep. The Benton beneath this sandstone contains Greenhorn limestone in its lower portion, and a few layers of sandstone which at some localities yield slight flows.

EDMUNDS COUNTY.

Edmunds County extends from the summit of the Bowdle Hills eastward into the James River valley, its altitude ranging from 1,400 to slightly over 2,000 feet. Under a mantle of glacial drift there is a thick mass of Pierre shale and the underlying formations, including several hundred feet of Dakota sandstone. The first deep boring in the county was at Ipswich, where a large volume of water was found at a depth of 1,265 feet under a pressure claimed to have been 120 pounds. In 1891 a pressure of 106 pounds was measured, indicating a head sufficient to raise the water to 1,775 feet above sea level. This is somewhat greater than is found in the wells at Aberdeen, just to the east, and 140 feet less than in the well at Shelby. The head is sufficient, however, to afford artesian flows in all the eastern part of the county and probably, from the indication of the Shelby well, as far west as the base of the Bowdle Hills, some distance west of Roscoe, where the altitude is from 1,900 to over 2,000 feet. The first well at Ipswich did not prove satisfactory and another one, sunk in 1902, obtains a 150-gallon flow from a depth of 1,245 feet. In the summer of 1903 it was reported that there were 83 deep artesian wells in the county, mostly of medium size, but furnishing an abundance of excellent water for farm and stock purposes. Some data in regard to these wells are given in the following table:

Artesian wells in Edmunds County.

Township.	Range.	Depth.	Average yield per minute.	Township.	Range.	Depth	Average yield per minute.
		Feet.	*Gallons.*			*Feet.*	*Gallons.*
121	66	987–1,100	12–35	122	71	1,526	2
121	67	1,025–1,155	20–50	123	66	1,075–1,125	25
121	68	1,155–1,250	40–50	123	67	1,305–1,360	35
121	69	1,240	25	123	68	1,526	97–150
121	70	1,300–1,370	35	123	69	1,075–1,125	30
121	71	1,500–1,569	20	123	70	1,498	3½
122	66	1,000–1,100	15–70	124	66	1,125–1,148	40– 41
122	67	1,000–1,190	5–35	124	67	1,150–1,175	35–120
122	68	1,145–1,180	20–35	124	68	1,225–1,350	25– 45
122	69	1,305–1,360	35–70	124	69	1,356	60

FALL RIVER COUNTY.

Fall River County lies on the south slope of the Black Hills uplift, with the Dakota sandstone and underlying formations outcropping to the west. Cheyenne River cuts a deep valley across the uplift, but is deflected by it considerably to the south. The land presents much variety of configuration, having wide areas of undulating plains to the south and hogbacks of the Dakota sandstone to the north. There is a great diversity of geologic structure and distribution of the formations. To the south are broad areas of the Pierre shale, from under which the regular succession of Niobrara, Benton, Dakota, and underlying formations rise to the north. The general rise of the beds is to the north, but there is a main anticline which extends up Hat Creek valley and pitches beneath Pine Ridge to the south. Another steeper; but less extensive, arch lies east of Maitland, and

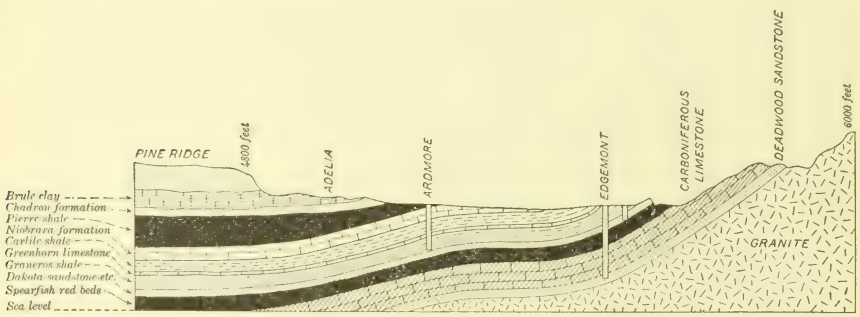


FIG. 5.—Section from the Black Hills to Pine Ridge across Fall River County, showing relations of the water-bearing Dakota and associated sandstones, looking west.

two smaller arches extend southeastward from Edgemont and into the southeast corner of the county from the Pine Ridge Reservation. Between these anticlines are synclines, or basins, which in the vicinity of Oelrichs and farther south hold fully 1,200 feet of the Pierre shale, with the Dakota sandstone more than 2,000 feet beneath the surface. The basin west of Hat Creek is much shallower, the greatest depth of the Dakota sandstone probably not being much more than 2,000 feet on the highlands west of Ardmore. Figure 5 gives a north-south section across the county.

A number of wells have been sunk in Fall River County, some of which have reached the Dakota sandstone, while others have failed to do so. At Argentine a well in that sandstone yields a flow and at Edgemont some wells obtain water from it which has not sufficient head to flow. It is probable from these results that in all of the county underlain by the Dakota sandstone water supplies may be obtained, though flows can be had only in the extreme northwestern portion, and on the slopes between the hogback and Cheyenne River in the

northeastern portion. At Minnekahta a deep boring begun in the "Red Beds" penetrated far into the underlying formations, but was unsuccessful. The new 2,980-foot well at Edgemont yields a large flow from the Deadwood sandstone that underlies the entire county.

Edgemont.—In this city and its vicinity a number of wells were sunk several years ago in search of water from the Dakota sandstone. Nearly all obtained supplies for pumping, but owing to the low altitude of the outcrops of the sandstone a short distance to the east the water does not have sufficient head to flow. The water did not prove satisfactory for use in locomotives, and all but the deeper well at the railroad roundhouse have been abandoned. This well, of which the record is given below, had a depth of 1,125 feet, but is now filled to the depth of 700 feet.

Record of deep well at Edgemont.

	Feet.
Shale	0– 295
Sand, white; water	295– 325
Soft white bed	325– 350
Fuson shale	350– 430
Sandstone, white, with 10-foot soft white bed at base	430– 455
Shale, light colored	455– 497
Limestone	497– 509
Sandstone, white; water	509– 604
Sandstone, dark	604– 612
Sandstone, white above, red below	612– 652
Shale, with 7-foot layer of limestone at base	652– 705
Shale, light colored	705– 752
Soft white bed	752– 802
Sundance, upper dark shale	802– 957
Sandstone, red	957– 977
Sandstone; bad water	977–1,012
Sundance, lower shale	1,012–1,125

Water of bad quality was found in the white sand at 295 feet and in the sandstone at 977 feet. Fairly good water, rising within 60 feet of the surface, is now obtained from the sandstone that begins at 509 feet. It contains 239 grains of solid matter per gallon, of which 9.33 grains are lime. The log appears to be fairly reliable, indicating the Dakota sandstone at 295 to 350 feet; the Fuson formation at 350 to 430 feet; the Lakota sandstone at 430 to about 652 feet; the Morrison shale at 652 to 802 feet; the characteristic red series in the Sundance formation at 957 to 977 feet; the bed of buff sandstone in the Sundance at 977 to 1,012 feet; and the basal dark shales in the Sundance at 1,012 to 1,125 feet. The well at the north end of the Y across the river from Edgemont, has a depth of 960 feet and probably ends in the shales of the Sundance, but the record appears not to be reliable in its details. Some water was found in the white sand at 230 feet and in sandstones at 290 and 430 feet.

At 578 feet a sandstone begins which yields a good supply of water, rising within 30 feet of the surface. A thin sandstone at 700 feet also yields water, but its volume is small. The record is as follows:

Record of deep boring at the Y, near Edgemont.

	Feet.
Sand and gravel	0– 30
Shale	30–230
White sand water	230–260
Shale, with 10-foot sandstone layer at base	260–300
Shale	300–430
Sandstone, etc	430–460
Sand and shale	460–485
Sand	485–505
Shale	505–578
Sand, white, with 5-foot layer of shale	578–618
Sandstone, water	618–643
Shale, with 5-foot layer of sandstone	643–703
Shale	703–960

In June, 1905, the Chicago, Burlington and Quincy Railroad Company began a boring intended to go to 3,000 feet if necessary, to test the water resources of the formations below the "Red Beds." In the spring of 1907 a depth of 2,980 feet was reached. A flow found at 2,920 feet finally furnished more than 300 gallons a minute as boring progressed. The pressure is 75 pounds and the temperature 122°. At first the water contained much mineral matter, evidently derived from flows in the red sandstones at higher horizons, for the boring was not cased between 1,850 and 2,111 feet. A 5-inch casing inserted to the latter depth cut off this water, and the main supply was then found to be satisfactory for use in locomotives. The following record is compiled from the log furnished by the company, with slight modifications based on examinations of samples sent by the drillers and others:

Record of artesian well at Edgemont.

	Feet.
Clay	1– 25
Clay, mixed with sand and gravel	25– 33
Drab shale	33– 35
Shale	35– 90
Sandstone	90– 98
Shale	98– 110
Soft dark shale	110– 150
Slate	150– 190
Black shale	190– 269
Shale	269– 297
Hard sandstone	297– 300
White, gray, and black shale	300– 343
Limestone	343– 347
Pink shale	347– 349
Limestone	349– 354

	Feet.
White shale	354–363
Limestone	363–371
Red and white sandy clay	371–375
Hard dark shale	375–377
Hard sandstone	377–398
Dark shale	398–404
Hard sandstone	404–407
Iron pyrites (?)	407–409
Gray shale	409–415
Hard rock	415–417
Shale	417–420
Hard limestone	420–431
Hard sandstone	431–434
Hard sandstone and dark shale	434–440
Hard light shale	440–449
Soft light shale	449–450
White shale	450–456
Soft shale	456–462
Sandstone	462–472
Hard limestone	472–486
Sandstone	486–489
Hard shale	489–493
Sandstone	493–503
Hard light shale	503–508
Hard sandy shale	508–524
Hard sandstone	524–544
Sandy limestone	544–559
Sandy shale	559–618
Red sandstone	618–644
Hard sandy shale	644–669
Water-bearing sandstone	669–672
Hard gritty shale	672–697
Hard sandy shale	697–740
Soft shelly limestone	740–750
Limestone	750–764
Sandy shale	764–774
Light sandstone	774–841
Hard sandy shale	841–855
Blue shale	855–955
Sandstone	955–965
Red gritty shale	965–1,040
Hard dark-red sandstone	1,040–1,051
White sandy shale	1,051–1,060
Blue shale	1,060–1,080
White sandstone; water rose to surface	1,080–1,098
Blue shale	1,098–1,157
Black hardpan	1,157–1,174
White sandstone (some water)	1,174–1,223
Gray limy shale (black hardpan?)	1,223–1,230
Red shales and sandstones	1,230–1,850
Red sandstone	1,850–1,955
Limestone, light colored	1,955–2,140

	Feet.
Light brown impure limestone	2,140–2,198
Red sandstone, very hard and sharp	2,198–2,203
Red rock (soft and caving first 24 feet)	2,203–2,278
Red sandstone	2,278–2,292
Limestone	2,292–2,303
Red and gray sandstone	2,303–2,325
White limestone, sandy	2,325–2,352
Sandstone, some lime; reported as limestone	2,352–2,440
White limestone	2,440–2,516
Red sandstone	2,516–2,537
Brown sandstone, some lime	2,537–2,572
Light-brown sandstone, no lime	2,572–2,641
Black iron pyrites	2,641–2,648
Soft red rock	2,648–2,700
Light-red rock	2,700–2,760
Red rock	2,760–2,878
Sandstone; first flow between 2,920 and 2,948 feet	2,878–2,890
Red rock; very hard 6-inch bed at 2,964 feet	2,890–2,980

According to another report the beds from 2,203 to 2,648 feet were buff sandstone, and those from 2,648 to 2,658 feet deep-brown sandstone containing much lime.

The identity of some of the rocks given in this record is questionable, especially the so-called limestones, and the limits of the various beds are not by any means accurate. Apparently the Dakota sandstone was reached at a depth of 297 feet, and presumably the base of the Lakota sandstone is the water-bearing sand from 669 to 672 feet. The Morrison and Sundance formations lie next below, with the sandstone in the lower part of the Sundance extending from 1,174 to 1,223 feet. The Spearfish began at 1,230 feet (according to another authority, at 1,255 feet, capped by 15 feet of coarse gray sand) and red beds continued with great uniformity to 1,955 feet, presenting a thickness of more than 700 feet, somewhat more than was expected from the amount in the Red Valley outcrops to the north. It is probable, however, that the Minnekahta limestone was penetrated above 1,955 feet and that the Opeche red sandstone is included in this thickness. Possibly, also, some of the top sandstone of the Minnelusa is included on account of its red color. The identity of the lower beds is difficult to establish. Many feet of the sandstones and limestones are Minnelusa. The base of the Pahasapa (and Englewood) limestones appears to be at the bottom of the thick body of limestone at a depth of 2,516 feet. The beds below this to 2,920 feet are mostly sandstones and shales, largely red, but some of the sandstones are snuff colored and very like the upper part of the Deadwood sandstone. No samples were obtained from the "sands" at 2,920 to 2,980 feet on account of the heavy flow of water.

As the Deadwood sandstone is less than 100 feet thick in the outcrop zone along the southern side of the Black Hills uplift, it is somewhat unexpected to find a thickness of 462 feet at Edgemont, which would be indicated if the formation begins at a depth of 2,516 feet. It is strongly probable that at 2,980 feet the boring is in the basal Deadwood sandstone near the Algonkian schist and that this sand furnishes the flow. The water passes underground near Pringle at an altitude of nearly 5,000 feet, so that the pressure of 75 pounds at Edgemont (3,440 feet above sea level) is not surprising.

An analysis of the water made for the railroad company ten days after the well was cased is as follows:

Analysis of water from deep artesian well at Edgemont, S. Dak.

[Hypothetical compounds.]	Grains per gallon.
Sodium chloride	16.19
Sodium carbonate	1.69
Calcium sulphate	14.29
Calcium carbonate	3.85
Magnesium carbonate	9.68
Silica and insoluble	1.18
Total solids	45.88

Grains per gallon by evaporation, 48.17. The water does not foam in boilers and the solids wash out easily.

Minnekahta.—Several years ago the Burlington and Missouri River Railroad Company made a deep boring at Minnekahta station to obtain a water supply for locomotives. A depth of 1,348 feet is said to have been attained, but no promising amount of water was reported. The record, which is given below, is clearly unreliable and very unsatisfactory for the identification of the geologic formations. No clew is given as to the location of the Minnekahta limestone, which should be expected to begin at about 400 feet below the surface at Minnekahta station. The red sands from 743 to 908 feet are doubtless in the Minnelusa formation, and possibly the red shale at 1,105 feet is the one at its base. At a depth of 1,348 feet the boring should be near the Deadwood sandstone, for the thickness of the formations from the base of the Sundance through the Pahasapa is not much more than this in the surface exposures in the region to the north. The references to gypsum at various depths in the boring are mistakes as to the identity of the material, except possibly those near the top. It is to be deeply regretted that the record is not more accurate, for it could have thrown important light on the stratigraphy.

Record of deep boring at Minnekahta.

	Feet.
Soil and gravel	0– 12
Gypsum (?)	12– 47
Sandstone	47– 62
Gypsum (?)	62– 107
Red gypsum (?)	107– 173
White gypsum (?)	173– 308
Red sand	308– 378
Flint	378– 388
Red rock	388– 428
White gypsum	428– 443
Red sands	443– 523
Quartzite (?)	523– 538
Red sand	538– 558
Limestone (?)	558– 581
Blue sand and rock	581– 611
Limestone (?)	611– 643
Sand rock	643– 663
Gypsum (?)	663– 743
Red sand	743– 908
Gypsum (?)	908– 990
White sand	990–1,022
Marble	1,022–1,082
Gypsum	1,082–1,105
Red shale	1,105–1,190
Pebble rock, with 8-foot layer of pyrites (?)	1,190–1,232
Black gypsum (?)	1,232–1,284
Crystalline gypsum	1,284–1,307
Red sand	1,307–1,325
White sand	1,325–1,348

Ardmore.—At Ardmore, on the Chicago, Burlington and Quincy Railroad, 26 miles south of Edgemont, the railroad company has made a boring to a depth of 1,500 feet without obtaining water. The hole is entirely in shale, except about 40 feet of white sand containing thin partings of black shale. This boring begins about at the surface of the Niobrara formation and apparently penetrates very nearly to the Dakota sandstone, the sandstone bed reported probably being in the Graneros shale. As the altitude of Ardmore is 3,557 feet, and the water-bearing Dakota sandstone outcrops about Edgemont at an altitude of 3,400 feet, there is no possibility of a flow at the former place, but probably a supply of water for pumping could be obtained by slightly deepening the boring into the Dakota sandstone. The estimated altitude to which the water would rise in such a well is about 3,450 feet. The structure here is shown in figure 5.

Argentine.—This station is a water-tank siding on the Chicago, Burlington and Quincy Railroad, 17 miles northwest of Edgemont. The well is on the south side of Pass Creek. It is a flowing well, 550

feet deep, yielding a fairly large volume of water, but of a quality not satisfactory for locomotives, as the following analysis shows:

Analysis of artesian water at Argentine

	Grains per gallon.
Sodium sulphate	39.90
Potassium sulphate	.90
Lime sulphate	4.20
Lime carbonate	6.00
Magnesia carbonate	4.00
Alumina and iron oxide	.05
Silica	.19
Total solids	56.60
Organic matter	.55

This analysis was kindly furnished by the railroad company. The log of the boring was not obtainable. The well begins in Graneros shale and undoubtedly obtains its water supply from the Lakota sandstone, which outcrops in the high ridge to the east.

Hot Springs.—At the Soldiers' Home, a short distance west of Hot Springs, a well was sunk some time ago to a depth of 223 feet. It began just above the top of the Minnekahta limestone, and obtains a moderate water supply from the Minnelusa sandstone.

FAULK COUNTY.

The geologic relations in Faulk County are almost precisely similar to those in Edmunds County. The western portion of the county lies high on the slopes of the morainal hills of the Bowdle Range, and the eastern portion extends far out on the low level lands of the James River valley. Many wells bored in the county within the last few years indicate that the Dakota sandstone is water bearing throughout and that the waters are under sufficient head to afford flows, except possibly at one or two very high points in the extreme southwest corner. As the strata lie nearly level, dipping very gently toward the west from the vicinity of Faulkton, the depths of the wells increase mainly with the rise of the land, which is slightly higher toward the center of the county. There appears to be considerable variability in the horizon of the principal flow, many of the wells having had to be sunk considerably below the top of the sandstone to obtain water in satisfactory volume. The only reports of pressure which have been received are from the old well at Faulkton, which indicated 25 to 34 pounds per square inch at a time when it was partly clogged up. The old well 4 miles north of east from Orient is reported to have had a pressure of 130 pounds to the square inch before it was clogged, which would indicate a water head of about 1,865 feet above sea level. This well had a depth of about 1,215 feet, a flow of 950 gallons per minute, and a diameter of 6 to 5¼ inches. Flows were reported in a

thin bed of lime rock at 394 feet, at 1,070 feet, and at 1,165 feet, where the principal supply was obtained. The materials penetrated are reported to have been as follows:

Record of well in sec. 18, T. 117, R. 68, near Orient, Faulk County.

	Feet.
Yellow clay	0– 20
Blue clay	20– 47
Shales, black, blue, and gray, with thin layer of lime rock at base furnishing small flow	47– 394
Shales, gray, blue, and black	394–1,070
Hard sandstone	1,070–1,110
Sand, lime, pyrites, and shale	1,110–1,165
Sandstone; 950-gallon flow	1,165–1,215

A list of artesian wells in the county is given below:

Artesian wells in Faulk County.

Township.	Range.	Depth.	Average yield per minute.	Remarks.
		Feet.	*Gallons.*	
117	66	913–1,054	45– 65	
117	68	1,095–1,156	90	
117	69	1,232	60	
118	67	1,016–1,075	60– 75	First flow at 850 feet.
118	69	1,220–1,466	25– 40	Pressure in one well 60 pounds.
118	70	1,183–1,608	45–100	
119	67	1,030–1,117	20	
119	68	1,165	150	
119	69	1,206–1,456	25–100	
119	70	1,367–1,402	100–185	
119	71	1,545	45	
120	67	1,039–1,060	50–150	
120	68	1,025	25	Pressure 85 pounds (?).
120	69	1,197–1,287	10–125	
120	70	1,342–1,512	12–100	
120	71	1,505–1,570	27– 35	
120	72	1,580–1,650	30– 70	

GRANT COUNTY.

Grant County lies on the eastern slope of the east coteau, extending from an altitude of over 2,000 feet near Summit to less than 1,000 feet at the foot of Bigstone Lake, in the Minnesota Valley. To the east there is a thick mass of glacial drift constituting the coteau, underlain by the Pierre shale, which extends nearly to the old granites exposed in the vicinity of Bigstone. The Dakota sandstone underlies the greater part of the county and appears to abut against the granite floor as this old rock surface rises to the northeast, but the position of its margin is not known. A boring at Milbank is said to have reached a depth of 303 feet, the lower 20 feet of which was in granite. A thin deposit of water-bearing gravel is reported lying on this rock, containing fossils, and overlain by 200 feet of shale, capped by 75 feet of blue clay that is doubtless of Quaternary

age. It has been supposed that the basal bed is the Dakota sandstone, but possibly it is in the Benton. A number of other wells in the valley bottom to the west and south yield satisfactory flows at various depths, but the pressure is too low to afford a flow on the upper slopes and summit of the coteau.

The available facts concerning the artesian wells of the county are given in the following table:

Artesian wells in Grant County.

	Depth.	Diameter.	Average yield per minute.	Remarks.
	Feet.	*Inches.*	*Gallons.*	
Mrs. Johanna Schultz, SW. ¼ sec. 30, T. 118, R. 47.	155	2	65	Water rises to +25 feet.
Ed. Redman, SW. ¼ sec. 14, T. 118, R. 48.....	57	1,2	40	
Milbank.....	393	. . .	Several.	20 feet into granite.
Will Marquette, NE. ¼ sec. 9, T. 118, R. 48...	206	3	3	Water rises to +4 feet.
W. H. Koepke, NE. ¼ sec. 22, T. 120, R. 48.	407	2	2	Water rises to +36 feet.
J. W. Newenburg, SE. ¼ sec. 18, T. 120, R. 49..	422	2	10	Water rises to +17 feet.
W. B. Saunderson, NW. ¼ sec. 7, T. 120, R. 49.	510	2	30	Water rises to +32 feet.
Mehegan & Fairchild, NE. ¼ sec. 11, T. 120, R. 49.	379	2	½	Water rises to +2 feet.
Julius Runge, NE. ¼ sec. 13, T. 120, R. 49.....	459	2	45	Water rises to +38 feet.

GREGORY COUNTY.

Gregory County lies in the southeast corner of the portion of the State west of Missouri River. It extends along the west side of the river for about 50 miles, and comprises the high plateaus extending southwestward to Ponca Creek and beyond. On the river banks and on some of the slopes to the west the Niobrara chalk is exposed, overlain in the highlands by the Pierre shale, which is capped to the south by Tertiary and Quaternary deposits.

The thickness of the Niobrara formation appears to be about 200 feet. It is underlain by 400 feet or more of Benton shales lying on the Dakota sandstone. This sandstone contains artesian water, which has been tapped by a number of wells on Whetstone Creek and by the old well at Fort Randall. The pressure in these wells indicates that the head of the waters along the river is about 1,800 feet to the north and slightly over 1,500 feet to the south and probably increases to 1,850 feet in the southwest corner. This head is sufficient to afford flows only along Missouri and Whetstone valleys and in the lower and middle slopes rising from them to the plateau. It is insufficient to give a flow at Bonesteel, at Fairfax, or in the Ponca Valley.

The depth to the Dakota sandstone averages from 700 to 800 feet along Missouri River, 1,200 feet in the eastern portion of the plateau, and somewhat more than 1,500 feet in the higher lands in the central, western, and southwestern townships. The wells in Whetstone

Valley are from 714 to 890 feet deep and yield large flows of good water.

The well at Fort Randall, sunk by the Government many years ago, has a depth of 610 feet and is reported to have the following record:

Record of well at Fort Randall, Gregory County.

	Feet.
Gumbo and clay	0–100
Soft stone	100–460
Sandstone; 600-gallon flow	460–520
Blue clay	520–576
Very hard rock	576–610

This record is probably very inaccurate, but it appears to indicate that the Dakota sandstone was entered at a depth of 460 feet, or very much nearer the surface than would be expected from the experience of wells on the other side of the river. Possibly the flow is from a sandstone in the Benton group, but the large volume of water is difficult to account for on this supposition. It is claimed that the hard rock in the bottom of the well was granite or quartzite, but this also is very uncertain.

HAMLIN COUNTY.

Hamlin County is on the summit of the east coteau, between the James and Minnesota river valleys. Its surface consists of a great thickness of glacial drift lying on the Pierre shale. Apparently it is underlain also by the Dakota sandstone at a depth averaging but little more than 1,000 feet throughout. As the altitude of the land is from 1,650 to about 1,900 feet, it is too high for an artesian flow, the probable head of the water in the Dakota sandstone being only about 1,600 feet. So far as known no endeavors have been made to reach the formation.

HAND COUNTY.

Hand County lies partly on highlands of drift and partly on the lowlands of the James River valley, the former rising to an altitude of somewhat over 2,000 feet in Ree Heights, and the latter having an average elevation of 1,400 feet. The surface is entirely covered by glacial materials, but these are underlain by a thick mass of Pierre shale and by the usual succession of Niobrara and Benton shales and Dakota sandstone. The Dakota has been reached by numerous wells, which afford flows in the central, northern, and eastern portions of the county. The head of the water averages slightly more than 1,850 feet about Miller and due north, increasing somewhat to the west and decreasing to 1,700 feet in the northeast corner of the county. In the highlands of the southern half of the county the elevation is considerably too great to afford flowing wells, but the

precise extent of the nonflowing area has not been ascertained. A well 1,611 feet deep, in the NW. ¼, sec. 21, T. 110 N., R. 68 E., is in this area, and although it penetrated the Dakota sandstone the water failed to reach the surface by 80 feet. The water-bearing beds in the Dakota sandstone occur at several horizons, but the principal flows are found at some distance below the top bed of the formation. Different wells in the region vary somewhat as to the horizon of the principal flow. The strata lie nearly level or undulate very gently. A faint anticline appears to extend north and south through Miller, but it is very low.

Record of town well in Miller, Hand County.

	Feet.
Soil, clay, and gravel	0– 220
Blue shale	220– 930
Hard sandstone and pyrites	930– 975
Shale (cap rock at 1,105 feet)	975–1,105
Sandstone, 460-gallon flow	1,105–1,145

Artesian wells in Hand County.

	Depth	Depth to water.	Diameter.	Average yield per minute.	Remarks.
	Feet.	*Feet.*	*Inches.*	*Gallons.*	
L. L. Eiles, NW. ¼ sec. 21, T. 110, R. 68	1,611		2		Water rises to −80 feet.
Peter Myers, NE. ¼ sec. 28, T. 110, R. 68	838		1¼	50	
C. Rowen, NE. ¼ sec. 8, T. 111, R. 66			1¼		
H. D. Ellis, SW. ¼ sec. 26, T. 112, R. 67	1,269		2 1¼	40	
M. N. Strickling, SW. ¼ sec. 26, T. 112, R. 67	1,246			40	
St. Lawrence, sec. 7, T. 112, R. 67	1,272	1,050 1,272		Few.	Pressure 40 pounds.
R. T. Sedam, sec. 18, T. 112, R. 67	1,343	1,315	3	350	Pressure 125 pounds.
John Baldwin, sec. 33, T. 112, R. 67	1,375	1,343	3	1,350	Pressure 119 pounds.
J. McCullam, SW. ¼ sec. 2, T. 112, R. 68	1,158		1¼	135	
Township well, sec. 7, T. 112, R. 68	1,200		4	50	
W. H. Smith, sec. 10, T. 112, R. 68	1,140	1,110	3½		
Miller, sec. 10, T. 112, R. 68	1,139	1,112	6¼–4½	360	Pressure 120 pounds.
Miller, Lost Creek Ranch Co	1,142	1,142 1,030	3-2	40	
Joseph Koeck, sec. 11, T. 112, R. 69	1,207	1,100 1,207	2	100	Pressure 60 pounds.
N. Noble, SW. ¼ sec. 20, T. 113, R. 66	1,058		1¼	35	
A. B. Holmes, sec. 11, T. 113, R. 66	980		2	100?	Water rises to +20 feet.
Ick Brown, sec. 24, T. 113, R. 66	980		1¼	35	
Will F. Pantsah, SW. ¼ sec. 15, T. 113, R. 66	967		1¼		
D. Conkey, SE. ¼ sec. 14, T. 113, R. 67	1,155		2½		
A. S. Piper, SE. ¼ sec. 15, T. 113, R. 67	800	1,087	2		
Township well, sec. 25, T. 113, R. 67	1,137	1,127 1,100			
W. W. Cotton, SE. ¼ sec. 25, T. 113, R. 67	1,140	1,112 1,129	3	100	Pressure 128 pounds.
Mr. Escher, SW. ¼ sec. 29, T. 113, R. 68	1,125	1,105	3		
Gus Merion, SE. ¼ sec. 33, T. 113, R. 69	1,214		1¼	60	
Chas. Fuller, NE. ¼ sec. 13, T. 113, R. 69	1,162		2	100	
Mr. Wyland, NW. ¼ sec. 14, T. 113, R. 69	1,215	1,190	2		
Township well, T. 113, R. 69	1,200				
Sam Bushong, sec. 11, T. 114, R. 66	1,050		1¼	35	
Frank Yodes, W. ½ sec. 35, T. 114, R. 66	1,010		1¼	35	
Thomas Jones, SE. ¼ sec. 27, T. 114, R. 68	1,272				
A. Gilmore, NE. ¼ sec. 12, T. 114, R. 68	1,050		1¼	40	
Thomas E. Eaton, SW. ¼ sec. 9, T. 114, R. 68	1,185	1,185	1¼	30	
J. C. Harris (?), SE. ¼ sec. 14, T. 114, R. 69	1,197		2		
Oliver McGee, sec. 15, T. 114, R. 70	1,303		3 1¼	15 or 25	
John J. Stornif			3		In progress, 1903.
H. Schoefers, SE. ¼ sec. 10, T. 115, R. 69			2		
Nabor Bros., NW. ¼ sec. 24, T. 115, R. 69	1,242			16	
J. B. Carl, SW. ¼ sec. 28, T. 115, R. 70	1,300		2	100	
D. Countryman, sec. 26, T. 116, R. 67	853		1¼		

HANSON COUNTY.

Hanson County is in the James River valley, its northern portion extending into the artesian basin. As the greater part of the county lies on the summit of the old buried ridge of Sioux quartzite, the Dakota sandstone is mostly absent. In the part of this area northeast of Mitchell, northwest of Spencer, east of Ethan, and on James

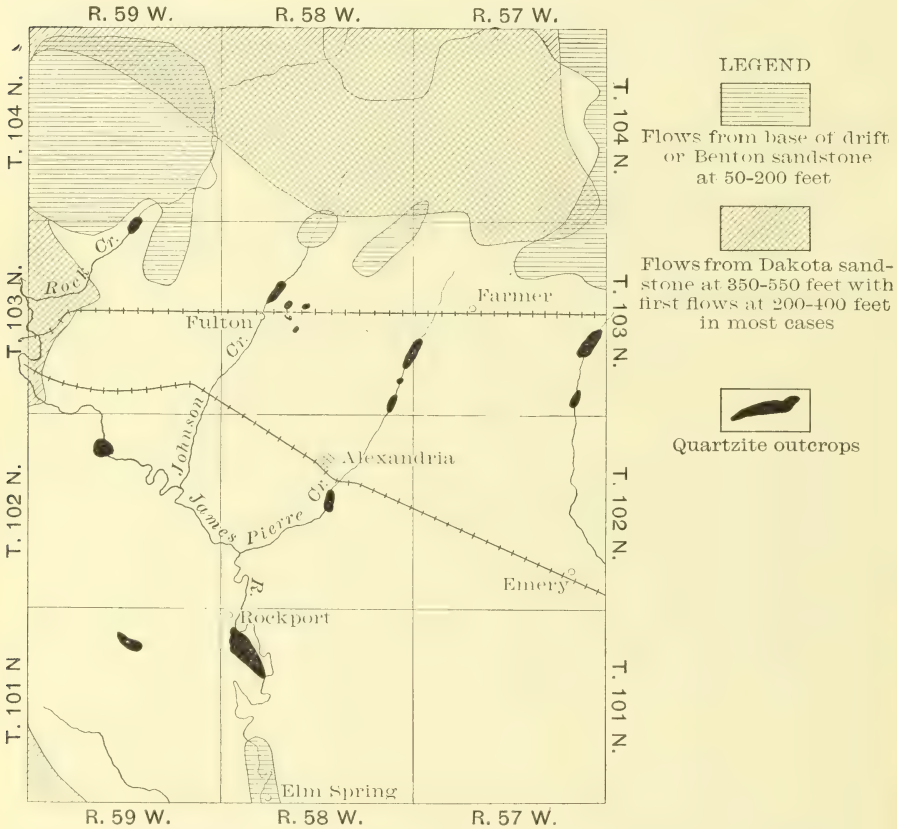


FIG. 6.—Map of Hanson County, showing artesian conditions. By the late C. M. Hall. No flows have been obtained in the white area.

River about Elm Springs, overlapping sandstones in the Benton group are sources of small artesian supplies. Small flows that are also obtained from the base of the drift are probably due to leakage from the Benton horizon. East of Mitchell the upper beds of Dakota sandstone appear to lie in a valley in the quartzite ridge for some distance and to contain water which affords flows on the lower lands along James River and on the slopes and upland just north of the mouth of Rock Creek.

In the northwest corner of the county there is an area of about 30 square miles in which excellent flows are obtained from sandstone in the Benton group in wells 80 to 200 feet deep and from the base of the drift in shallower wells. These conditions continue to the east at intervals through the northern tier of townships, especially in the district north of Spencer. (See fig. 6.)

Artesian wells in Hanson County.

Township.	Range.	Depth.	Average yield per minute.	Remarks.
		Feet.	*Gallons.*	
101	58	112		
103	56	112, 150	Several.	Flows from base of drift north of Spencer only.
		165, 260	Several.	Flows from upper sandstone of Benton north of Spencer only.
103	57	127	Several.	Flows from base of drift in sec. 11 only.
103	57	155–290	5–40	Flows from upper sandstone of Benton in northeastern sections only.
103	57	400	Many.	In sec. 4 from sandstone in Benton group.
103	58	140	Several.	
103	59	135–176	Several.	Flows from base of drift.
103	59	400–470	Many.	Flows in northwestern sections only.
103	59	410	None.	Insufficient head for flow in sec. 18.
104	56	80–145	Several.	Flows from base of drift in western sections.
104	56	167–260	Several.	Flows from upper sandstone of Benton in western sections.
104	57	152–170	Several.	Flows from base of drift.
104	57	170–365	½–5	Flows from sandstones of Benton.
104	57	508–600	4–50	
104	58	90	Several.	Flows from base of drift.
104	58	175–365	Several.	Flows from sandstones of Benton.
104	58	440–555	30–150	No flows in secs. 30, 31, 32, and 33.

The main artesian basin extends under the greater part of T. 104 N., Rs. 57 and 58 E., in the northeastern and north-central parts of the county, where there are numerous wells 400 to 589 feet deep. They furnish large flows and usually have first flows also from sandstone in the Benton, which is the source of small flows in numerous wells 200 to 300 feet deep. A typical deep-well section in Hanson County is as follows:

Record of Knapp well, in sec. 13, T. 104, R. 58, Hanson County.

		Feet.
Yellow clay.	Drift	0–20
Blue clay...	Drift	20–123
Coarse sand with small flow..	Benton	123–188
Black shale	Benton	188–208
Coarse sand with water	Benton	208–218
Blue shale	Benton	218–230
Sand	Benton	230–235
Shale, dark above, lighter below	Benton	235–535
Soft sandstone, with 150-gallon flow from 2-inch pipe (Dakota)..		535–550

HUGHES COUNTY.

Hughes County extends from the Missouri Valley eastward on to the highlands. Most of the surface is covered with glacial deposits which are underlain by several hundred feet of Pierre shale. Under this is the usual succession of Niobrara formation, here mostly shale, Benton shales and sandstones, and Dakota sandstone lying on granite or quartzite. The sandstone is water bearing and the water appears to be under sufficient head to afford flows throughout the county. Its depth varies from 1,000 feet in the Missouri Valley at the south margin of the county to about 1,600 feet in the highest lands in the northwest portion. The beds dip gently to the northwest.

There are several wells at Pierre and vicinity, one at Harrold, and another just to the north in Sully County. The three wells at Pierre are 1,160, 1,256, and 1,537 feet deep, the two latter having, it is asserted, passed through the sandstone to granite. The greatest pressure reported is 210 pounds to the square inch, sufficient to raise the water to an altitude of 1,920 feet above sea level. The Pierre wells yield large flows of water, with considerable gas, which has been found useful. The following record is reported by Mr. Swan, the driller:[a]

Record of well at Pierre, Hughes County.

	Feet.
Sand and gravel	0– 62
Gray shale	62– 87
Black shale	87– 275
Blue shale	275– 325
Light-gray shale	325– 425
Dark-gray shale	425– 476
Lime rock, hard	476– 479
Blue shale	479– 530
Lime rock (hard)	530– 533
Blue shale, soft above, with gas	533– 650
Hard sandstone	650– 654
Blue shale; small first flows at 870 and 890 feet	654–1,085
Streaks of lime and shale	1,085–1,130
Sand rock, yellowish; flows of water and gas	1,130–1,140
Streaks of lime and sand	1,140–1,175
Sand rock, yellowish; flows of gas and water	1,175–1,185
Streaks of shale, lime, and sand	1,185–1,215
White sand, soft; main flow, 210 pounds pressure, temperature 89°	1,215–1,245
Streaks of white shale and lime	1,245–1,250
Granite	1,250–1,256

Todd reports that there is no question as to the identity of the granite claimed to have been penetrated for 6 feet at the bottom of the well. Another well sunk recently a short distance farther west found

[a] Bull. South Dakota Geol. Survey No. 2, 1898, pp. 93-94.

the granite at a depth of 1,537 feet, a discrepancy difficult to account for.

The well at Harrold is at the altitude of 1,081 feet, and the water is under sufficient pressure to rise 62 feet higher, yielding a flow of 84 gallons per minute from a 4-inch pipe. The well is 1,453 feet deep and has the following record:

Record of well at Harrold, Hughes County.

	Feet.
Glacial deposits	0– 125
Blue shale	125– 280
Limestone	280– 282
Blue shale	282– 450
Gray shale, with limestone layers	450– 550
Gray shale, with limestone layers in its lower portion	550–1,435
Sandstone	1,435–1,451
Brown shale	1,451–1,453

HUTCHINSON COUNTY.

Hutchinson County is partly in the James River valley and extends up the slopes of the adjoining highlands to the east and to the west. The surface is mostly covered by glacial drift, but in some of the valleys there are outcrops of Niobrara chalkstone and the sandstone at the top of the Benton group. The Dakota sandstone underlies the greater part of the county, but to the north abuts against the Sioux quartzite and ends, the overlying formations extending beyond, up the slopes of an underground ridge. The formations all dip gently toward the southwest along the slope of this ridge.

The depth to the Dakota sandstone is slightly less than 300 feet along James River, gradually increasing in the higher lands to the west and to the east. In the southwest corner of the county the sandstone lies nearly 800 feet beneath the surface, and in the southeast corner 700 feet. It contains large volumes of water under considerable pressure, which is sufficient to afford flows in the lower lands but not in the higher areas in the eastern and extreme southwestern portions of the county. There are several horizons of flow in the region, beginning with sandstones in the Benton and comprising two or three thick sandstone layers in the Dakota. These are tapped by numerous wells in the northwestern, central, and southern portions of the county. Some of the wells obtain their waters from the top of the sandstone, and others penetrate to lower horizons to obtain increased volume and pressure.

In the eastern portion of the county several wells have been sunk to quartzite which found no water or found only supplies in the Benton sandstones that lacked sufficient head to flow. Flows are obtained from the Benton sandstones at Elm Springs and at some

other points in the area in which the Dakota sandstone is absent, and from this source several wells in the region to the west have obtained supplies of moderate volume. The principal features of the representative wells in this county are set forth in the following table:

Artesian wells in Hutchinson County.

Township.	Range.	Depth.	Average yield per minute.	Remarks.
		Feet.	*Gallons.*	
97	56	445–480	.....	No flow.
		122	27–60	Flows from base of drift.
97	57	65–154	3–10	Flows only in valleys, from base of drift.
		417	Few.	Low pressure; Menno town well.
		406–630	Many.	Pressure 25 pounds.
		747	6	
97	59	480–620	30–50	Pressure 25 to 35 pounds; several flows.
		300	Few.	Flows from sandstone in the Benton.
		500	1	Sec. 26.
97	60	540–614	40–50	
		648–760	50–100	Pressure 35 to 60 pounds.
		824	700	Pressure 9 pounds; Tripp town well.
97	61	30– 62	6	Flows from base of drift.
		945	.....	
98	56	53– 54	4–9	Do.
98	57	55– 65	1–3	Do.
98	58	420	.....	
98	59	40–200	Several.	Flows from base of drift and upper sandstone in the Benton.
		370–450	1–15	
98	60	470–580	16–120	
		120–189	Several.	Do.
98	61	482–560	13–60	
		64–130	6–10	Flows from base of drift.
99	56	54– 95	10–12	Do.
99	57	150	.....	Wolf Creek.
99	58	270–335	1–10	
		280	.....	No flows in northern section.
99	59	365–490	Many.	
		118	Many.	Flows from base of drift.
99	60	470–540	5–150	
		100–130	Many.	Do.
		360–440	.....	First flows from lower sandstones of the Benton.
		542	30	Pressure 20 pounds; Parkston town well.
99	61	515–535	10–50	Pressure 13+ pounds.
		140	.....	Flows from base of drift.
		490–572	8–50	
100	59	180–220	.....	First flows from lower sandstones of the Benton.
		240–345	.....	No flow.
100	60	560	10	
		370–462	3–10	First flows from lower sandstones of the Benton.
		296–340	Many.	Flows from upper sandstone of the Benton.
100	61	419–585	1–90	

The wells at Tripp and Parkston have the following records:

Record of well at Tripp, Hutchinson County.

	Feet.
Drift	0– 25
Chalkstone (probably a portion of these 300 feet comprises light-colored clays in the lower part of the drift deposits)	25–325
Sandstone (top of the Benton)	325–425
Shale	425–525
Sandstone	525–529
Shale	529–729
Sandstone and shale	729–764
Sandstone with flowing water	764–824

Record of well at Parkston, Hutchinson County.

	Feet.
Yellow clay	0– 40
Sand with water	40–225
Blue shale	225–434
Gray shale with water	434–444
Gray shale	444–460
Fine sandstone	460–472
Shales, with hard layers above and sand layers below, with flow	472–542
Very hard rock	542

HYDE COUNTY.

Hyde County extends north and south along the summit of the high divide between the Missouri and James River valleys, the higher portions of which attain an altitude of over 2,000 feet above sea level. The surface is thickly covered with glacial drift, with underlying Pierre, Niobrara, and Benton shales more than 1,400 feet thick, lying on Dakota sandstone. Three borings have been reported—one at Highmore, with a depth of 1,552 feet; another at the Mitchell the ranch, 8 miles northeast, with a depth of 1,397 feet; and a third at Begun ranch, in the NE. ¼ sec. 30, T. 114 N., R. 71 E., 1,380 feet deep, with a 30-gallon flow and 30 pounds pressure. All obtain flows from the Dakota sandstone. The pressure in the Highmore well is stated to be 12 to 15 pounds to the square inch, indicating a head of 1,920 feet above sea level, a pressure insufficient to afford flows on the high summits south of Highmore and on the high ridges northwest.

The well at Highmore is at an altitude of 1,890 feet; the depth is 1,552 feet, diameter 6 inches, and flow about 9 gallons per minute. The principal flow was obtained from a depth of 1,537 feet. Nonflowing water was found in a bed of sandstone, probably in the Benton group, extending from 1,430 to 1,442 feet. The following is the log of this well:

Record of town well at Highmore, Hyde County.

	Feet.
Soil, clay, and gravel	0– 240
Blue shale	240– 740
Hard gray shale, pyrites	740– 815
Blue shale	815–1,086
Gray shale mixed with sand	1,086–1,310
Shale and pyrites	1,310–1,314
Blue shale	1,314–1,430
Sandstone; no flow	1,430–1,442
Sandy shale, on bed of hard sand	1,442–1,537
Soft sandstone	1,537–1,552

JERAULD COUNTY.

Jerauld County extends from the western part of the James River valley onto the high drift ridges to the west. The surface is covered with drift lying on Pierre shale. Under this shale there is the usual succession of Niobrara chalkstone, Benton shales and sandstones, and Dakota sandstone lying on granite and quartzite, the beds dipping gently to the north.

The Dakota sandstone contains water under pressure sufficient to afford flows except on the highlands in the central portion of the county. There are numerous wells with large flows in the eastern third of the county, which average for the most part from 715 to 850 feet in depth and furnish large volumes of water under pressure of 90 to 132 pounds, indicating that flows may be expected in all portions of the area having an altitude of less than 1,700 feet. The following is a list of the wells that have been reported:

Artesian wells in Jerauld County.

Township.	Range.	Depth.	Average yield per minute.	Remarks.
		Feet.	*Gallons.*	
106	63	715–760	200–280	Pressure 110 to 132 pounds.
106	64	735–880	5–280	Pressure 114 pounds.
107	64	860	35	
107	65	1,200	1	
108	63	785	500	Water irony.
108	64	799?	2	
		840–865	45	
108	65	1,057	200	Pressure 90 pounds.

Records of some typical wells in Jerauld County are as follows:

Record of well of S. H. Albert, sec. 5, T. 108 N., R. 65 E., Jerauld County.

	Feet.	
Drift	0–	47
Shale, with layers of pyrites and a layer carrying many shells at 290 feet	47–	400
Chalkstone	400–	415
Shale (top of Benton)	415–	460
Sandstone; contains water	460–	490
Shales, with sandstone layers	490–	586
Shale	586–	705
Hard rock	705–	725
Shale, with thin limestone at 801 and thin sandstone at 845 feet	725–	899
Sandstone; small flow	899–	914
Compact shale	914–	1,003
Hard sandstone (top of Dakota)	1,003–	1,043
Sandstone, with 200-gallon flow	1,043–	1,057

In the well of P. Schultz, in sec. 9, T. 106 N., R. 64 E., the first water was found under chalk at 290 feet below the surface, and the Dakota

sandstone was reached at 836 feet and yielded a 280-gallon flow at 880 feet.

Record of well of E. Schmidt, sec. 14, T. 108 N., R. 64 E., Jerauld County.

	Feet.
Drift	0–100
Limestone	100–104
Shale (Pierre)	104–254
Chalk	254–349
Chalk or sandstone, with water	349–369
Shale	369–649
Sandstone, with flow	649–654
Shale	654–840
Sandstone, with main flow	840–841

Record of well of K. Feistner, NW. ¼ sec. 2, T. 106 N., R. 63 E., Jerauld County.

	Feet.
Drift	0– 40
Shale	40–100
Chalkstone	100–160
Sandstone at top of Benton	160–170
Shale	170–500
Sandstone with flow	500–501
Shale	501–701
Top sandstone of Dakota, with main flow	701–721

KINGSBURY COUNTY.

The artesian conditions in Kingsbury County present considerable variety, the lower lands in the western portion of the county lying sufficiently low to be within reach of flowing water, while to the east, in the higher coteau country, the land is too elevated for flows from the Dakota sandstone horizon. The entire county is underlain by Pierre shale overlain by Pleistocene deposits, which have considerable thickness in the coteau region to the east. Many wells, most of which yield large flows, have been bored in the western part of the county. The first one sunk was at Iroquois, where, at a depth of 1,115 feet, a flow of 1,000 gallons per minute was obtained. The well penetrated the Pierre, Niobrara, and Benton. Small flows were found in thin sandstone layers at 400 and 600 feet, and the main flow was struck in the Dakota sandstone, which was entered at 847 feet. The pressure was reported to be 67 pounds per square inch in 1890, but a determination in 1899 gave 71 pounds. Other wells have since been sunk, mostly in the western portion of the county, having depths of 815 to 1,120 feet and yielding from 20 to 100 gallons a minute, with surface pressures of 8 to 50 pounds to the square inch. Several wells in various places obtain water supplies from a sandstone horizon just below the first great body of shales, probably at the top of the Benton group, but these have to be pumped.

The surface of the Dakota sandstone slopes gently northwestward, with slight local undulations. East of a line passing north and south near Manchester the land rises abruptly to the northeast from an average altitude of 1,500 feet to over 1,800 feet on the summit of the coteau. As the head of the water in the Dakota sandstone is from 1,550 to 1,615 feet on the west and 1,680 at De Smet, it is evident that no flows are obtainable in the wide coteau area.

The following is a list of the deep borings so far reported in the county:

Deep borings in Kingsbury County.

	Depth.	Average yield per minute.	Remarks.
	Feet.	*Gallons.*	
S. E. Matthews, sec. 30, T. 109, R. 57	925	80	Pressure over 20 pounds.
K. Singerson, sec. 8, T. 109, R. 58	815	90	
Esmond	870	75	
F. H. Horton, sec. 29, T. 109, R. 58	840	Many.	
Sec. 29, T. 109, R. 58	845	100	
H. H. Welch, sec. 35, T. 109, R. 58	906	50	Pressure about 20 pounds.
T. 109, R. 58	600, 640	.....	Water rises nearly to surface.
Do	400–500	.....	Several wells; water level −30 to −50 feet.
Arlington	786	.....	No flow.
E. Gulbransere, sec. 18, T. 110, R. 57	970	20	Pressure 8 pounds.
Spear well, sec. 19, T. 110, R. 57	940	60	Pressure 27 pounds.
Iroquois	1,115	1,000	Pressure 67 pounds; main flow from 850 to 900 feet.
Sec. 28, T. 110, R. 57	1,056	.....	No flow.
Sec. 23, T. 110, R. 57	1,055	Few.	
Sec. 20, T. 110, R. 57	930	Several.	
Sec. 34, T. 110, R. 57	1,050	Several.	
A. N. Waters, sec. 28, T. 110, R. 58	850	35	
De Smet	1,610	.....	Water rises to −20 and −40 feet from several strata.
Sec. 32, T. 111, R. 56	500	Many.	No flow.
Sec. 5, T. 111, R. 57	600	Many.	Do.
Sec. 28, T. 111, R. 57	1,090	.....	
Sec. 31, T. 111, R. 57	970	30	
De Smet, sec. 22, T. 111, R. 58	943	Many.	Pressure 50 pounds.
J. Burcheding, sec. 24, T. 111, R. 58	1,010	18	
C. G. Swefford, sec. 34, T. 111, R. 58	850	50	
Hetland, sec. 19, T. 112, R. 53	710	None.	Dry hole.
T. 112, R. 56	375, 600	Many.	Water level −100 feet.
William Rusche, sec. 7, T. 112, R. 57	1,120	4	Pressure 15 pounds.
W. Solcey, sec. 3, T. 112, R. 58	1,000	40	Pressure 40 pounds.
Andrew Mears, sec. 14, T. 112, R. 58	1,030	20	Pressure 30 pounds.
Brooks well, sec. 21, T. 112, R. 58	1,045	Many.	
S. Mann, sec. 30, T. 112, R. 58	947	10	
R. C. Purington, sec. 35, T. 112, R. 58	1,040	45	

The following records show the principal geologic features in some representative wells in Kingsbury County:

Record of artesian well at Iroquois.

	Feet.	
Clay	0–	45
Shale	45–	400
Sand, with water	400–	402
Shale	402–	600
Sand, with water	600–	602
Shale	602–	850
Sandstone, with 1,000-gallon flow	850–	900
Shale	900–	1,100

The shale from 45 to 400 feet is probably comprised in the Pierre and Niobrara formations, the latter here consisting of materials not sufficiently calcareous to be reported as chalkstone, a deposit which characterizes the formation farther south. In this well the formations of the Benton group extend from 400 to 847 feet, where the top of the Dakota sandstone was entered.

Another well 4 miles northeast of Iroquois, on land 100 feet higher than the Iroquois well, obtains a large flow from a depth of 916 feet with a pressure of 50 pounds.

Record of Brooks well, east side sec. 21. T. 112, R. 58, Kingsbury County.

	Feet.
Yellow and blue clay	0– 113
Shale	113– 400
Sandstone, with water	400– 450
Shale	450–1,030
Sandstone, with large artesian flow	1,030–1,045

This record is very similar to that of the Iroquois well, 9 miles to the southwest. The sandstone extending from 400 to 450 feet probably represents the sandstone bed which usually characterizes the top or upper portion of the Benton group in eastern South Dakota and furnishes water for many deep-pumped wells in portions of Kingsbury County and elsewhere.

Record of Spear artesian well, NE. ¼ sec. 19, T. 110, R. 57, Kingsbury County.

	Feet.
Yellow clay	0– 36
Blue clay and sand	36–140
Black shale	140–390
Gray shale	390–485
Sandstone; water rising to—111 feet	485–505
Gray shale	505–862
Sand; some water	862–863±
Shale	863–932
Sandstone; 60-gallon flow	932–937
Hard rock	937–940

The black shale from 140 to 390 feet is undoubtedly Pierre, and apparently the gray shale below represents the Niobrara. The water-bearing sandstone extending from 485 to 505 feet is the usual feature at or near the top of the Benton group, and the sandstone entered at 932 feet is the Dakota, with a large volume of water showing a surface pressure of 27 pounds.

Record of deep boring at De Smet.

	Feet.
Clay	0– 44
Sand	44– 104
Shale	104– 840
Hard rock	840– 865
Sandstone; water rising to —40 feet	865– 985
Shale, or "soapstone," with fish teeth at 1,145 feet	985–1,185
Sandstone; water rising to —40 feet	1,185–1,456
Hard rock	1,456–1,470
Sandstone; water rising to —20 feet	1,470, 1,610

This boring was sunk with the hope of finding an artesian flow, but was unsuccessful owing to the height of the land. It is claimed that a large volume of water was found, but it failed to reach the surface by 20 to 40 feet. The first 104 feet of the boring are in drift, and from 104 to 1,185 feet it goes through the Pierre, Niobrara, and Benton. In one log the first water-bearing sands were reported from 763 to 793 feet, and in another from 865 to 985 feet; probably both were in the top of the Benton group. The hard rock from 840 to 865 feet may be a limestone such as occurs in the lower part of the Niobrara formation in some regions. A stratum, said to be 1 foot thick, largely composed of fish teeth, was reported at a depth of 1,148 feet, apparently in the lower formation of the Benton group. The Dakota sandstone appears to have been penetrated from 1,185 to 1,610 feet, a thickness of 425 feet, without reaching its base. This boring shows that probably no flows are obtainable on the coteau.

A well at Arlington is reported to have reached a depth of 786 feet without obtaining a flow. It is almost certain that it did not reach the Dakota sandstone, which probably lies at a depth of 1,100 feet. As the altitude of the town is 1,846 feet and the head of the water in the Dakota sandstone is probably less than 1,700 feet, a flow could not be expected.

The following record of the Arlington boring has been reported:

Record of deep boring at Arlington.

	Feet.
Loam and clay	0– 10
Dark-yellow clay	10– 50
Blue clay	50–210
Grayish clay	210–370
Blue shale	370–785
Sandstone	785–786

Another similar deep boring was sunk at Hetland, in sec. 19, T. 112 N., R. 53 E., but was entirely dry.

Record of deep boring at Hetland.

	Feet.
Black loam	0– 2
Yellow clay	2– 50
Blue clay	50–285
Soft yellow clay	285–310
Shell rock	310–360
Yellow clay	360–420
Blue shale	420–710

Record of deep boring in SW. ¼ sec. 35, T. 109 N., R. 58 E., Kingsbury County.

	Feet.
Yellow and blue clay	0– 80
Shale	80–420
Chalk rock	420–(?)
Soapstone and shale and hard layers	(?)–760
First flow	760
Sandstone, shale	760–836
Cap rock	836–883
Water-bearing sandstone	883–893
No more water	893–906

Record of deep boring in SE. ¼ sec. 30, T. 109 N., R. 57 E., Kingsbury County.

	Feet.
Yellow till	0– 40
Blue clay	40– 60
Black shale	60–282
"Soapstone" and chalkstone	282–493
Shales with hard streaks	493–593
Gray shale	593–746
Sandstone	746–770
Soapstone, sandstone, and shale	770–907
Cap rock	907–915
Sandstone	915–928

A well recently bored in the eastern part of sec. 28, T. 110 N., R. 57 E., is reported to have reached a depth of 1,056 feet and obtained water in the Dakota sandstone, which rose within 20 feet of the surface. Quartzite was found at the bottom of the boring. Another well in the SW. ¼ sec. 23 of the same township of about the same depth obtained water which rises to the surface, but with so low a pressure that the flow is very slight. Hard rock also stopped boring operations in this well. A 1,050-foot well in sec. 34 and a 930-foot well in sec. 20 have good flows but they are on lower ground.

LAKE COUNTY.

A buried valley in the quartzite and granite, which extends north and south through the center of Lake County, apparently contains the Dakota sandstone, but the altitudes of the land are too great for the formation to afford a flow.

At Madison a boring was sunk to a depth of 1,082 feet, which appears to have been mainly in shale and to have obtained no water supply. Lime rock, which was reported from 490 to 570 feet, resting on sandstone, suggests the Niobrara chalk, but aside from this there is no evidence as to the geology of the boring. As the bedrock surface is known to rise rapidly to the west, south, and east, it is evident that there is a deep trough at Madison, probably opening to the north, as shown in Plate X. Whether this trough contains the Dakota sandstone or not remains to be demonstrated, but if it does it is not to be expected that its water will have sufficient head to reach the surface, which at Madison is 1,669 feet above sea level.

LAWRENCE COUNTY.

Lawrence County is on the northeastern slope of the Black Hills uplift, extending far into the region of crystalline rocks to the south and out on the plains of Benton shales to the northeast. In the northern half of the county the rocks dip mainly to the north and northeast and pass underground in regular succession from the old crystalline schists to the Benton shales. In the extreme northeast corner of the county the Dakota sandstone lies about 1,000 feet below the surface in a shallow syncline which pitches to the north. Probably its greatest depth in the county is 900 feet, in the ridges northeast of St. Onge.

Doubtless the sandstone would yield flowing water in the lower lands, as indicated by the experience of wells at Belle Fourche, a short distance farther north. It is probable that in the Red Valley in this county underground waters could be obtained by sinking into the Minnelusa sandstone, and possibly also in the underlying Deadwood sandstone. The depth from the middle of the Spearfish red beds to the top of the Minnelusa sandstone is about 500 feet, the top of the Deadwood sandstone lying about 1,000 feet deeper.

A recent boring at the electric-light plant in the canyon 1½ miles south of Spearfish has a depth of 415 feet. Water which flowed 20 gallons a minute was found at 323 feet in yellow sandstone of the Minnelusa. The flow increased to 50 gallons as this formation was bored through to its bottom at 398 feet. The Pahasapa limestone was penetrated for 17 feet but yielded no water.

A well 2½ miles northwest of Spearfish, in the NW. ¼ sec. 4, T. 6 N., R. 2 E., 312 feet deep, obtains a flow of 15 gallons from a depth of 305 feet. The city of Spearfish is sinking a well to obtain a flow from the Minnelusa sandstone.

LINCOLN COUNTY.

Apparently only the extreme southwest corner of Lincoln County is underlain by the Dakota sandstone, and it is believed that the

water of that formation does not have sufficient head to reach the surface in flowing wells. The Sioux quartzite rises to the surface in the northeastern portion of the county and slopes gently to the southwest, where it is overlain by a greater or less thickness of Benton shales and Niobrara chalk.

LYMAN COUNTY.[a]

Lyman County extends from Missouri River 85 miles westward over the plains lying between Bad and White rivers. It is underlain almost entirely by the Pierre shale, except along the Missouri River and in its vicinity, where the underlying Niobrara chalkstone is exposed. A few of the higher points are capped by remnants of Tertiary deposits, notably at White Clay and Medicine buttes. Under the Pierre clay there is the usual succession of Niobrara chalkstone, Benton shales, and Dakota sandstone, the Dakota lying on the granite or quartzite to the east, but possibly overlapping rocks of Paleozoic and early Mesozoic age in the western portion of the county.

The Dakota sandstone contains water in large volume and under sufficient pressure to afford a flow in all the valleys and probably for some distance up the slopes. Owing to lack of knowledge of the topography of the county and the precise head of the waters in its western part, the nonflowing areas can not be accurately delimited. The water has been developed by several wells in the Missouri Valley opposite Chamberlain, by the McClure well on Cedar Creek, 18 miles south-southeast of Pierre, and by wells at Capa, Vivian, and Kennebec, on the new lines of railroad.

The Dakota sandstone in this county appears to dip gently westward and its depth also increases to the west by the gradual rise of the land in that direction. The wells on Missouri River reach it at a depth of about 550 feet, the amount increasing somewhat both up and down the river and rapidly in the highlands to the west. In the divide between Medicine Creek and White River it lies at least 1,400 feet below the surface to the east and at White Clay Butte somewhat more than 2,000 feet. On White River, at the western border of the county, probably the depth is nearly 1,700 feet, and on Bad River it is nearly 1,600 feet, as shown by the well at Capa.

Wells opposite Chamberlain.—The wells opposite Chamberlain are of moderate depth. One on the farm of G. S. Grant, in sec. 14, T. 104 N., R. 72 E., is 563 feet deep and 2 inches in diameter. The first flow was reported at 360 feet, the second flow at 460 feet, and the main flow at the top of the Dakota sandstone at 560 feet. Another well, on the farm of E. A. Barlow, on a bench a mile back from the river in the southern part of T. 104 N., R. 71 E., has a depth of 600

[a] Including southern portion of Lower Brule Indian Reservation.

feet and a diameter of 2 inches. Its flow is small. The Adams-Brinkehoff well in the NW. ¼ sec. 7, T. 104 N., R. 71 E., has a 2-inch bore, is 737 feet deep, and flows several hundred gallons per minute. The pressure of the water in these wells is not given, but to judge from that in the wells at Chamberlain, it is probably sufficient to raise the water to 1,800 feet above sea level.

McClure well.—The McClure well is in sec. 31 or 32, T. 108 N., R. 78 E., and has a depth of 1,653 feet. The inner tube is 1¼ inches in diameter and is reported to yield a flow of 40 gallons per minute with a pressure of 20 pounds. A special line of levels was run to this well, and it was found to be at an altitude of 1,917 feet, so that the pressure of 20 pounds indicates that the water at this place had sufficient head to rise to 1,963 feet above sea level, which, with the probable slight increase to the west, is sufficient to afford flows in portions of the county not on the higher divides. The record of the McClure well is reported as follows:

Record of McClure well, sec. 31 or 32, T. 108, R. 78, Lyman County.

	Feet.
Yellow shale	0– 20
Blue shale	20– 820
Black shale	820–1,090
Hard shale	1,090–1,094
Black slate with layers of hard limestone	1,094–1,294
Sandy shale	1,294–1,320
Black shale with sandy streaks	1,320–1,470
Muddy sandstone, black shale, and shelly limestone	1,470–1,510
Gray shale and fine sandstone mixed	1,510–1,550
Very hard rock	1,550–1,552
Shale	1,552–1,555
Sandstone	1,555–1,585
Sandy shale	1,585–1,623

There is some uncertainty in this record as to whether the Dakota sandstone was reached at 1,470 feet or 1,555 feet.

Capa.—A boring at Capa, a siding on the extension of the Chicago and Northwestern Railway from Pierre to Rapid, is 3 inches in diameter and has a depth of 1,689½ feet and a flow of about 100 gallons a minute. It has a 2-inch screen at the bottom. The temperature of the water is 118°. The materials penetrated were shale, which below 1,000 feet contained thin strata of limestone. The Dakota sandstone, was entered at 1,500 feet. Water began to flow 18 gallons a minute between 1,560 and 1,580 feet, and the main flow is at 1,650 feet. Gas was encountered at a depth of 1,560 feet and rises in considerable amount. The cost of this well was $2,676.

An analysis of the water from this well at a depth of 1,650 feet, made by G. M. Davidson, chemist of the Chicago and Northwestern Railway Company, showed that it contains the following ingredients:

Analysis of water from well at Capa.

[Hypothetical compounds.]	Grains per gallon.
Carbonate of lime	0.91
Carbonate of magnesia	.62
Oxides of iron and aluminum	.20
Silica	1.47
Alkaline chlorides	73.42
Alkaline sulphates	.26
Alkaline carbonates	85.95
Organic matter	3.71
Total solids	166.54

It is considered a poor water for boiler use on account of foaming.

Kennebec. A well sunk in 1907 at Kennebec, on the new railroad extension west from Chamberlain, is 1,301 feet deep and obtains a 50-gallon flow from the Dakota sandstone. The principal flow began at a depth of 1,246 feet, presumably at the top of the formation. The diameter of the well is 3 inches at the top, with intake through a 1¼-inch screen. The pressure appears to be moderate, but it was not gaged. The temperature of the flow is about 96°. The altitude of Kennebec is 1,688 feet.

Vivian. Vivian is a new station on the railroad 25 miles west of Kennebec, at an altitude of 1,895 feet. A well completed in 1906 to a depth of 1,610 feet yields a 20-gallon flow, and the principal water-bearing sandstone was entered at a depth of 1,530 feet. The size of the boring is the same as in the well at Kennebec.

Draper. Draper is on the high divide at the head of Medicine Creek, its altitude being 2,230½ feet. It is on the western extension of the Chicago, Milwaukee and St. Paul Railroad. A well bored by the railroad in 1907 has a depth of 2,005 feet and a diameter of 2½ inches, and yields 10 gallons a minute. The Dakota sandstone was penetrated for 130 feet. Owing to the height of the land the water does not flow, but it rises within 200 feet of the surface. It is lowered 200 to 300 feet by pumping.

Murdo McKenzie. A boring at Murdo McKenzie, the next station west of Draper, reached a depth of 2,135 feet. It entered sandstone, which only yielded a small water supply. The elevation of the land, 2,318 feet, is too great for a flow.

M'COOK COUNTY.

The area of artesian flows in McCook County appears to be restricted to the west half of the northwesternmost townships, where, in an area of about 35 square miles, there are several small flowing wells. These derive their waters either from the basal drift gravels or from the chalk below, in an extension of the shallow artesian region of Sanborn County. To the east and south the quartzite rises nearly to the surface and cuts off the source of supply.

The following list comprises all the flowing wells in McCook County from which returns were received:

Artesian wells in McCook County.

	Depth.	Average yield per minute.	Remarks.
	Feet.	*Gallons.*	
J. N. Dickens, sec. 8, T. 104, R. 56	123	30	In chalk rock.
J. F. Gurney, sec. 17, T. 104, R. 56	86	150	
N. G. Hall, sec. 21, T. 104, R. 56	175	$\frac{1}{10}$	
John Madkins, sec. 30, T. 104, R. 56	172	25	
F. J. Butler, sec. 6, T. 104, R. 56	95	40	Do.
John D. Hoafer, Bridgewater	113	.....	
Jacob Wahl, Bridgewater	160	$1\frac{1}{2}$	No flow.
Robert Glen, Bridgewater	196	.....	Do.

These wells, which are all of 2-inch bore, usually supply hard water. The yield of those that flow is reported to be decreasing.

The quartzite lies only 100 to 154 feet below the surface about Spencer, and at various depths from 150 to 500 feet or more in the region to the south and east. At Salem, according to Nettleton, it was found at a depth of 222 feet and was penetrated for 25 feet. Water which rose to within 75 feet of the surface was found in this boring in sand at a depth of 215 to 220 feet. At Bridgewater a similar water horizon was found at a depth of 224 feet, but the bottom of the boring, at 229 feet, did not reach the quartzite.

M'PHERSON COUNTY.

McPherson County lies largely upon the western coteau but also includes in its eastern part an extensive area in the valley of James River. In the highlands there is a thick deposit of glacial drift and the plain is mostly covered by Quaternary deposits of various kinds. The Cretaceous clays vary in thickness from about 1,100 feet in the southeast corner of the county to 1,600 feet or more in the highlands of the west, and these figures also represent the depth to the Dakota sandstone. This formation, containing a large volume of artesian water, underlies the entire county, but the head is only sufficient to afford flows up to altitudes of about 1,800 feet or possibly slightly less, to judge by the pressure in the wells on the higher slopes. During the last few years numerous wells have been sunk in the eastern por-

tion of the county and flows of large volume have been obtained. Most of the wells are on the plain at altitudes from 1,400 to 1,600 feet, but a number of them have recently been sunk on the lower slopes rising to the coteau. The following list includes all which have been reported:

Artesian wells in McPherson County.

Township.	Range.	Depth.	Yield per minute.	Township.	Range.	Depth.	Yield per minute.
		Feet.	*Gallons.*			*Feet.*	*Gallons.*
125	66	1,160	40	126	68	1,102–1,280	50
125	67	1,165–1,190	20–160	127	66	1,150	80
125	68	1,260–1,280	30–100	127	67	1,220–1,330	30–80
[a]125	69	1,507	8	[b]127	68	1,485	11
126	66	1,150–1,180	40– 60	128	66	1,170–1,280	25–40
126	67	1,230–1,290	30– 35	128	67	1,300–1,725	25–30

[a] In SE. ¼ sec. 24. [b] In NE. ¼ sec. 24.

MARSHALL COUNTY.

Marshall County includes the northern part of the high coteau and also extends westward across part of the plain of the James River valley. The coteau is a high ridge of glacial deposits which, together with the plain to the west, is underlain by a thick mass of Cretaceous clays. The Dakota sandstone underlies the entire county, having a depth of slightly less than 1,000 feet in the plain but being very much deeper under the highlands of the coteau. It has a very gentle dip to the west and lies on granite or other crystalline rocks which have been reached in a well at Veblen at a depth of 860 feet and in one at Britton at a depth of 1,030 feet. The sandstone is undoubtedly water bearing throughout, but as the maximum altitude of the head of the water is only about 1,700 feet, calculated from the pressure at Britton, and as the land on the summit of the coteau has an elevation of somewhat more than 1,750 feet, flowing wells are not obtainable in the east-central and southeastern portions of the county. The following is a list of wells in Marshall County so far as reported:

Artesian wells in Marshall County.

	Depth.	Yield per minute.	Remarks.
	Feet.	*Gallons.*	
T. 125, R. 58	960– 990	35– 50	Pressure 115 pounds.
T. 125, R. 59	925– 930	10– 25	Pressure 55 to 60 pounds.
T. 126, R. 56	980	60	Pressure 105 pounds.
T. 126, R. 57	890–1,125	10– 35	Pressure 50 to 70 pounds.
T. 126, R. 58	940– 965	10– 95	Pressure 75 pounds.
T. 127, R. 57	938–1,152	6– 40	
T. 127, R. 58	929	35	
T. 128, R. 58	930	30	
T. 128, R. 56	980	18	
Langford	1,050	400	Pressure 60 pounds; 6-inch well.
Britton	1,004	600	Pressure 150 pounds; 3½-inch well.
Newark	940	600	Pressure 125 pounds; 6-inch well.
Veblen	860	½	Pressure 15 pounds; salty water.

MEADE COUNTY.

Meade County extends northeastward from the flanks of the Black Hills to the divide between Owl River and Sulphur Creek. To the east it extends for some distance along the west side of Cheyenne River, and it comprises the lower portion of the Belle Fourche Valley. A wide range of formations is included within its limits, extending from the granites and schists in the Black Hills uplift to the lignite-bearing sandstones and shales in the highlands north of the Belle Fourche. On the slopes of the Black Hills the older rocks are exposed, dipping so steeply to the northeast that within a short distance they are carried to a considerable depth. The dip diminishes away from the hills and thence, to the northeast, the strata lie nearly horizontal.

The Dakota and associated sandstones are exposed in the hogback range, and to the east pass beneath the surface, so that along Belle Fourche River they lie at depths of 1,900 to 2,000 feet in the lowlands and of more than 2,500 feet on the divides. Probably they lie still deeper in the northeastern portion of the county. These sandstones contain artesian water, which enters at an altitude of 3,500 feet or more, so that it has sufficient head to afford artesian flows in the lower lands toward the east. A number of wells have been sunk to these sandstones in the region north of Sturgis and obtain large flows of excellent water. The following is a list of wells in the county:

Artesian wells in Meade County.

	Depth.	Depth to main flow.	Diameter.	Yield per minute.	Pressure.	Remarks.
	Feet.	*Feet.*	*Inches.*	*Gallons.*	*Pounds.*	
N. P. Hansen, NW. ¼ sec. 15, T. 6, R. 5.	1,116	1,090	2	35	.....	Flows 5 feet above surface; soft.
R. Stephens, NE. ¼ sec. 22, T. 6, R. 5.	377	357	2	60	50	Soft water.
K. F. Kambisch, sec. 20, T. 6, R. 5.	720	480	2	Many.	.....	No increase of water below 500 feet; water rises to —4 feet; soft.
J. S. Jensen, SE. ¼ sec. 8, T. 6, R. 5..	632	600	2	Many.	20	Water at 300 feet also; soft.
J. H. Enskert, sec. 26, T. 6, R. 5....	1,310	.....	.....	Small.	.....	In progress.
Bear Butte Oil Co., SE. ¼ sec. 8, T. 6, R. 5.	755	600	3¾	100	20	
W. H. Bowman, sec. 2, T. 6, R. 5...	1,560	.....	.....	4	Few.	
J. Dacy, 5½ m. E. of Whitewood, 3 m. N. and 2 m. W. of B. B. O. Co.'s.	570	570	.....	Many.	15	First flow at 330 feet.
Fort Meade (U. S.).....	1,450	322	.....	12	.....	No water below a good flow at 322 feet.

Wells north of Sturgis.—The first well in this district, in the SE. ¼ sec. 8, T. 6 N., R. 5 E., about 6 miles north of Sturgis, was completed in February, 1904. It was sunk for oil, but found a large flow of water at a depth of 600 feet, in an 85-foot bed of white Lakota sandstone. The well has a diameter of 3¾ inches and a total depth of 755 feet, and

the pressure is said to be sufficient to raise the water 35 feet or more above the surface. The following record is furnished:

Record of artesian well 6 miles north by west of Sturgis.

	Feet.
Dark shale	0–275
Light shale and sand	275–435
Red clay	435–505
"Rocks"	505–585
Soft sandstone with large flow of water at about 600 feet	585–670
Coal, 1 inch thick	670
Dry sand	670–685
Black shale with 2-inch coal	685–705
Green shale with thin limestone layers	705–755

A small flow was found at 440 feet. The altitude of the surface at this boring was 3,225 feet. It began in the Graneros shale, passed through 70 feet of the Fuson formation from 435 to 505 feet and through 180 feet of the Lakota sandstone, and penetrated 70 feet into the Morrison.

The well of Mr. Jensen is reported to have passed through 40 feet of surface material, 250 feet of shale, 10 feet of sandstone, 240 feet of hard shale, and 92 feet of sandstone which yields the water supply.

In the Stephens well the first 250 feet are blue shales, which are underlain by 25 feet of sandstone, followed by 82 feet of gray shales and 22 feet of sandstone containing water.

It is probable that in the Red Valley, in the western part of this county, the Minnelusa sandstone would be reached at moderate depths and would furnish water supplies, and it is possible also that waters under considerable pressure might be obtained from the underlying Deadwood sandstone, about 1,000 feet deeper.

Fort Meade.—Several years ago a well which was sunk by the quartermaster's department at Fort Meade, just east of the Dakota hogback range, developed a 12-gallon flow of excellent water at a depth of 322 feet. With the expectation of finding additional supplies it was continued deeper and went through the Spearfish red shales to the Minnekahta limestone, where, unfortunately, it was discontinued without testing the prospects of obtaining water in the upper part of the Minnelusa sandstone, 100 feet or more below. The record of this boring, based mainly on samples furnished by the quartermaster, is as follows:

Record of boring at Fort Meade, Meade County.

	Feet.
Sandstone and gravel	0– 25
Buff sandstone, fine grained	25– 50
Buff sandstone, coarser	50– 75
Buff sandstone, medium grained	75– 100
Gray shale	100– 125
Yellow sandstone, fine grained	125– 153

	Feet.
Gray shale	153– 185
Coarse sandstone, dark colored	185– 200
Gray sandstone; some shale	200– 225
Light-gray shale	225– 250
Dark shale with pyrite	250– 288
Sandstone, fine-grained basal Lakota, with shale layers	288– 322
Water of good quality, which rose 2 feet above the surface and flowed 10 to 12 gallons per minute	322
Light greenish-gray shale	322– 600
Very dark shale	600– 603
Blue shale	603– 745
Red shale	745– 770
Blue shale	770– 771
Red shale, with gypsum at 890 and 910 to 930 feet and some gray shale at 850 and 940 feet	771–1,440
Limestone (Minnekahta)	1,440–1,450

MINER COUNTY.

Miner County lies on the east side of the James River valley and extends eastward up the slope of the coteau, its western half lying in the Dakota artesian basin. The surface of the county is covered by glacial deposits, which lie on the Pierre shale in the central and northern parts and on the Niobrara chalkstone in the southern part. There is the usual succession underground of Niobrara and Benton underlain by Dakota sandstone, except in the east-central and southeast portions of the county, where this sandstone abuts against an underground ridge of Sioux quartzite, on which the overlying formations overlap toward the east. In the western half of the county the formations dip gently to the northwest, away from the quartzite ridge.

The depth to the Dakota sandstone is 375 feet in the southwest corner of the county; it increases gradually to the east and then to the north, being from 750 to 800 feet along the north margin. Throughout its extent the sandstone contains water under sufficient head to afford vigorous flows in the lower lands comprising the western half of the county. An 884-foot well at Carthage obtains a flow from a depth of 768 feet, and numerous deep wells in the southwestern townships obtain flows from the Dakota sandstone at depths of 380 to 550 feet. In these two southwestern townships flows are also obtained at depths of 150 to 250 feet from sandstones in the Benton, and also at depths of 50 to 140 feet from the base of the drift deposits. These shallow wells are numerous in the southwest corner of the county and afford excellent water supplies for local use. Ordinarily the deeper wells are sunk only where the shallower horizons do not afford sufficient supplies. In the central-western portion of the county there are

numerous wells about 400 feet deep which obtain water from the sandstone underlying the Niobrara chalkstone, but the water has to be pumped to the surface. The following is a list of wells in this county:

Representative artesian wells in Miner County.

Township.	Range.	Average depth.	Average yield per minute.	Remarks.
		Feet.	*Gallons.*	
105	56	73–146	5–75	Flows from base of drift.
		225–320	100	Flows from upper sandstone of the Benton.
105	57	55–150	2–50	Flows from base of drift.
		175–490	2–100	Flows from sandstones in Benton group.
105	58	100–140	10–60	Flows from base of drift.
		170–396	15–150	Flows from sandstones in Benton group.
106	56	80, 126	50–90	Flows from base of drift.
		450–465	.....	Nonflowing wells at Howard and Vilas.
106	57	66–120	3–100	Flows from base of drift.
		145–176	5–50	Water from upper sandstone of the Benton.
106	58	84–100	Many.	Flows from base of drift.
107	56	450, 580	Many.	No flow; good pump supply; soft water.
107	58	60	Many.	Flow from base of drift in section 31 only.
108	57	884	60	Carthage city well.
		408–450	Many.	No flow; good pump supply; soft water.
108	58	405–430	Many.	Do.

MINNEHAHA COUNTY.

The Dakota sandstone appears not to extend into Minnehaha County, unless possibly under a small area in its northwest corner. The Sioux quartzite has been reached by numerous borings at no great depth, and in many places is overlain by a greater or less thickness of Benton shales and Niobrara chalk. The quartzite outcrops extensively along Sioux River and some of its branches. In some places wells in this quartzite obtain a small amount of water from crevices, but a boring 575 feet deep at Sioux Falls failed to obtain any useful amount of water and was in quartzite throughout. It was found that the formation varied somewhat in hardness.

MOODY COUNTY.

The Dakota sandstone appears to be entirely absent in Moody County. The Pierre, Niobrara, and Benton formations lie on the Sioux quartzite, which outcrops in the southern portion of the county and has been reached by numerous wells to the north. Some of the sandy beds in the Benton yield small amounts of water, but without sufficient head to flow at the surface. Seven miles southeast of Flandreau the pipestone of the Sioux quartzite was penetrated for 230 to 236 feet under sand, shale, and sandy shale. About 5 miles west-southwest of the same town a well 455 feet deep found water in sand, and at Flandreau water is obtained in sand at a depth of 126 feet. The Sioux quartzite is reported at a depth of 100 feet north of Flandreau and at about the same depth 10 miles northeast of that place.

A well about 2 miles east of Trent is reported to have the following record:

Record of well in sec. 8, T. 105, R. 48, near Trent.

	Feet.
Yellow clay and blue clay	0–180
Sand; no water	180–192
Sandy clay	192–220
Sand; some water	220–230
Clay, with thin bed of sand at 300 feet	230–360
Sand, with main water supply	360–363

PENNINGTON COUNTY.

The geologic relations in Pennington County are very similar to those in Custer County, except that the dips on the east side of the Black Hills uplift average somewhat less. They are sufficient, however, to carry the Dakota and associated sandstones rapidly beneath the surface, so that at a distance of 10 miles east of the hogback range their top is at a depth of 2,000 feet. In the valley of Rapid Creek, in the eastern portion of the county, the sandstone is believed to lie at a depth of about 2,400 feet, and along Cheyenne River at depths of 2,100 to 2,300 feet, as nearly as can be estimated from a determination of the structure of the Pierre shale based on the distribution of the tepee butte zone. Several borings of moderate depth have been made east of Rapid, but they have not been sufficiently deep to reach the Dakota sandstone. It is stated that in one boring half a mile southeast of Rapid a sandstone, probably a sandy layer in the Benton, was penetrated at a depth of 400 feet and yielded a small flow. It is probable that the Dakota sandstone would yield flows throughout the portion of this county east of the hogback range, except on the higher divides. The prospects for underground waters in the Red Valley are the same as in Custer County.

A boring recently completed at Wasta on Cheyenne River is 2,287 feet deep. At 2,208 feet a three-foot bed of sandstone was penetrated which yields water rising to within 300 feet of the surface, here 2,315 feet above sea level. The supply is 40 gallons a minute with a 4-inch pump barrel at a depth of 900 feet. The sandstone evidently is the Benton, and it is greatly to be regretted that the boring was not sunk a few hundred feet deeper to test the Dakota and underlying sandstones, which doubtless would yield a strong flow.

PINE RIDGE INDIAN RESERVATION.

The large Pine Ridge Indian Reservation extends from the valleys of Cheyenne and White rivers onto the high table-land of Pine Ridge, comprising broad valleys, extensive badlands districts, and wide areas of high plains. The altitudes range from 2,100 feet or more in the White River valley, in the extreme northwest corner of the reservation, to 3,800 feet or more in the high ridges east of the

agency. The high plains are heavily mantled by soft sandstone of the Arikaree formation, and the lower slopes are occupied mostly by the underlying White River group, which has been exposed by erosion, giving rise to extensive badlands. In the northeastern and western portions of the reservation the Pierre shale is cut into by White and Cheyenne rivers, and in the extreme southwest corner Niobrara and Benton appear. The geologic structure is probably relatively simple, the strata in the eastern portion of the area dipping gently to the west and those in the western portion dipping gently to the east on the slope of the Black Hills uplift.

Along White River, in the southwest corner of the reservation, there is a sharp local uplift by which the Niobrara and the Benton are exposed. The depth to the Dakota sandstone varies considerably in the reservation, owing largely to variations in the altitude of the land. As the thickness of the overlying Benton, Niobrara, and Pierre has not been very accurately ascertained, the depth to the Dakota sandstone, as indicated on the map (Pl. XI), is only approximate, and for the south-central part of the reservation, where the Arikaree formation hides the underlying strata, no estimates can be made. The thickness of the Pierre shale doubtless reaches a thousand feet in the northwest corner of the reservation, but the amount diminishes gradually to the east. The Benton group, which has a thickness of somewhat more than 1,300 feet on the southeast slopes of the Black Hills, undoubtedly thins rapidly to the east, for it has less than half of that amount on Missouri River. The Niobrara chalk and associated deposits probably preserve a thickness of about 200 feet throughout. The White River beds lie on a somewhat uneven surface of Pierre shale, eroded so that its thickness varies considerably. From these factors it is believed that the Dakota sandstone lies at a depth of about 1,800 feet along White River in the extreme northeast portion of the reservation, and that the amount gradually increases toward the west, to 2,300 feet near Interior, a thickness which is probably uniform nearly to the mouth of White Clay Creek. Thence to the south the uplift brings the Dakota sandstone very much nearer the surface, so that near the state line on White River it is probably not more than 1,100 or 1,200 feet deep in the center of the anticline. At the Pine Ridge Agency the sandstone will probably be found at a depth of 1,400 to 1,500 feet. In the divide between White and Cheyenne rivers and in the badlands slope south of White River, east of the mouth of Wounded Knee Creek, the Dakota sandstone lies 2,500 feet or more below the surface.

To judge from the general slope of the head of the water in the Dakota sandstone between the Black Hills and the Missouri Valley and toward the east, it is probable that flowing water may be expected in the Pine Ridge Reservation in the valleys of Cheyenne and White

rivers, up to an altitude of 3,000 feet in the northwest corner, 2,600 feet in the north-central portion, and 2,200 feet in the eastern portion. This area comprises all the bottom lands, a moderate proportion of the slopes, and the lower portions of the valleys of the side streams of Cheyenne River and White River valleys below Interior post-office. According to the best estimates the Pine Ridge Agency is at an altitude of 3,300 feet, so that there is no probability of obtaining a flow in the White Clay Valley at that place.

POTTER COUNTY.

Potter County extends eastward from Missouri River, comprising a narrow area of lowlands in the valley with a rapid rise toward the east to an elevated undulating district of drift hills. Along the river the altitude is about 1,500 feet; in the highlands it is mostly about 1,800 feet, though in portions of them it is considerably above 2,000 feet. The region is underlain by a thick mass of Pierre shale mantled by glacial deposits and underlain by Benton and Niobrara shales and the Dakota sandstone. The sandstone contains a large volume of water under great pressure, as demonstrated by the well at the Cheyenne Agency, on the opposite side of Missouri River, and the well at Gettysburg. The agency well, having a pressure of 205 pounds to the square inch, indicates a head sufficient to raise the water to an altitude of 1,970 feet. The Gettysburg well, which is on land having an altitude of 2,082 feet, has a water level 108 feet below the surface, indicating a head of 1,974 feet. In the adjoining county to the east the head is less, indicating a rise to the west. Two wells on the highlands just east of Missouri River obtain satisfactory flows—one east of Forest City at 1,604 feet and the other south of Forest City at 1,761 feet.

From these facts it is evident that artesian waters would be available in Potter County in all but the very highest lands, which comprise the elevation on which Gettysburg is situated and the Bowdle Hills along the eastern margin of the county.

The Gettysburg well has a depth of 2,130 feet. It is 3 inches in diameter and yields soft water, the principal supply being found at a depth of 1,780 feet. The following record has been furnished by C. L. Nicholson, the driller:

Record of well at Gettysburg, S. Dak.

	Feet.
Black soil	0– 2
Yellow clay	2– 30
Blue clay	30– 180
Blue shale	180–1,430
Very hard rock	1,430–1,470
Sandy shale with much pyrites	1,470–1,780
Sand rock with water	1,780–1,980
Sandy shale	1,980–2,000
Sand rock	2,000–2,040
Sandstone and shale alternating	2,040–2,130

ROBERTS COUNTY.

Roberts County is in the northeast corner of South Dakota. It comprises a wide area of lowlands adjoining Bigstone Lake and Lake Traverse and its southwestern and west-central portions extend far up the slopes of the coteau. It is underlain mainly by Pierre, Benton, and Niobrara, but the granite comes to the surface in the southeast corner. Very few data are available as to the geology of this county, especially regarding the distribution of the Dakota sandstone. No reports of deep wells in this county have been received. The 465-foot well at Browns Valley, on the opposite side of the river, in Minnesota, has a small pressure, presumably from the thin eastern edge of the Dakota sandstone lying on granite. This and the wells at Milbank, in the county adjoining on the south, afford assurance that flows may be expected on the lower lands of eastern Roberts County. The scanty flow of salty water at Veblen, in the northeast corner of Marshall County, suggests that the conditions will not be favorable for satisfactory supplies in the northwestern portion of Roberts County.

ROSEBUD INDIAN RESERVATION.

The Rosebud Indian Reservation comprises about 5,000 square miles of the plains lying south of White River, in the south-central portion of South Dakota. The greater part of the surface is rolling, with numerous deep valleys draining into White River to the north or Missouri River to the east. The reservation also contains the headwaters of Ponca Creek and Keyapaha River. The altitudes range from somewhat less than 1,200 feet on Missouri River to 3,000 feet in the southwest corner of the reservation.

The predominating formation of the region is the Pierre shale, overlain in the higher lands of the south by White River and Arikaree deposits, and cut through by Missouri River, which exposes the underlying Niobrara chalkstone along the east side of the reservation. The beds lie nearly horizontal, dipping very slightly to the west. Beneath the Pierre shale there is the usual succession of Niobrara chalkstone, Benton shales, and Dakota sandstone. In the lower lands to the east this sandstone is less than a thousand feet below the surface, but to the west it lies deeper, and, in the higher lands southwest of the Rosebud Agency, is at a depth of at least 2,500 feet. On White River, in the northwest corner of the reservation, the depth is probably about 1,900 feet.

Only one boring has been sunk in this area. It is located on the highlands at the head of Oak Creek, on the divide between the White River and Keyapaha drainage. It was sunk by the Indian Bureau with the expectation of obtaining a flow that would fill some of the creeks with water, but this expectation was not realized. A depth of

2,500 feet was attained, and the Dakota sandstone was penetrated for several hundred feet, yielding water in moderate volume which rose within 500 or 600 feet of the surface. The ground at the well has been found by recent leveling to have an altitude of 2,626 feet, so that the water level at the well is between 2,026 and 2,126 feet above sea level. This head indicates that flows might be expected all along the White River valley and for some distance up the adjoining valleys and slopes, probably to the western margin of the reservation. This altitude of head probably increases slightly to the west, toward the Black Hills, and decreases to the east, as shown by the experience of wells along the Missouri River valley. Adjacent to this valley there is sufficient head to afford flows far up the slopes, but not on the wide areas of high plains in the eastern portion of the reservation. (See Pl. XI.)

The Rosebud well was put down in 1895, 1896, and 1897, and, while a costly experiment, has thrown very important light on underground-water conditions over a wide area of south-central South Dakota. The depth of the boring is 2,500 feet. It was cased with 8-inch casing to 2,145 feet, and below that with 6-inch casing. The following record is based on samples kindly furnished by Mr. Wright and Doctor McChesney, the Indian agents:

Record of the Rosebud well, Rosebud Indian Reservation.

	Feet.
Tertiary sands and clays	0– 350
Dark-gray shales	350–1,390
Water which rose to —1,140 feet	1,390
Light-gray shales, with water at 1,490 feet	1,390–1,550
Light-gray limy shales	1,550–1,730
Dark shales	1,730–1,860
Sandstone and limestone	1,860–1,880
Hard sandstone, with water rising to —600 feet	1,880–1,885
Shale, darker below	1,885–1,920
Hard sandstone	1,920–1,950
Soft shales, with thin limestone bed at 2,060 feet	1,950–2,075
Unknown	2,075–2,100
Gray sandstone, hard at top	2,100–2,140
Soft shale	2,140–2,150
Porous sandrock, with considerable water which rose within 500 (?) feet of the surface	2,150–2,175
Unknown	2,175–2,210
Shale	2,210–2,240
Sandstone	2,240–2,290
Gray shale	2,290–2,292
Fine-grained sandstone with some shale and pyrites; water mainly at 2,295 feet	2,292–2,500

The upper 350 feet belong to the Arikaree formation and the White River group. The Pierre shale underlies these formations to a depth of about 1,550 feet, having thus a thickness of 1,200 feet, to the

Niobrara chalkstone, which appears to begin at a hard limestone layer and to comprise nearly 200 feet of limy clays, extending to a depth of 1,730 feet. The underlying shales with thin beds of sandstone and limestone belong to the Benton group, which extends to at least 2,100 feet, where thick beds of sandstone begin and continue thence to the bottom, probably representing the Dakota sandstone for the lower 200 feet, at least. The volume of water in the sandstone in this well was not thoroughly tested, but it was the idea of the drillers that it was moderate, which is surprising when the large flows in some of the wells to the north and east are considered. The sandstones in the well are very fine grained, and on this account much less permeable than in some other localities. It is unfortunate that this boring was not continued through the Dakota sandstone to test the water pressure in the lowermost beds and to explore underlying formations in which water might be expected to have still greater head.

It is probable that this region is underlain by the eastern extension of some of the sedimentary formations older than the Dakota sandstone, which are so prominent in the Black Hills.

SANBORN COUNTY.

Sanborn County lies in the James River valley and comprises a very important portion of the Dakota artesian basin. It is underlain by the Pierre shale, Niobrara chalk, Benton shales and sandstones, and Dakota sandstone, lying on a floor of quartzite and granite, all dipping gently to the north. The surface is deeply covered by drift and superficial deposits, and there are no outcrops of the underlying rock, all knowledge of them being derived from well records. The Pierre shale underlies the northern portion of the county only, the drift in the southern portion being underlain by the Niobrara chalk.

The depth to artesian water increases at a nearly regular rate from north to south, except that in the James River valley, which is excavated to a depth of about 100 feet below the surrounding plains, the depths are correspondingly less. The Dakota sandstone, usually near its top, is the principal source of water supply, though sandstones at various horizons in the Benton group also afford flows of moderate volume. In the east-central portion of the county, about Artesian, there is an area of considerable extent in which flowing waters are obtained from the base of the drift at depths mostly from 50 to 110 feet, the water probably having its source through leakage from the upper sandstone of the Benton. This sandstone is a persistent member throughout the greater part of the region and is reached by many wells of moderate depth, especially in the district about Letcher. The depth to the Dakota sandstone averages from 340 to 450 feet along

the southern margin of the county, increasing to 475 feet in the higher lands to the west and diminishing to less than 300 feet in the valley of James River. To the north the depth increases regularly; along the northern margin of the county it is about 750 feet on the higher lands and 700 feet in the trough of the James River valley. The waters have considerable head, the altitude of which is about 1,400 feet in the southern part of the county, 1,500 feet in the central and eastern parts, 1,600 feet about Woonsocket and farther north, and about 1,550 feet in the northeast corner. This head is indicated by a pressure of 130 pounds to the square inch at Woonsocket and of 90 to 130 pounds to the square inch in the vicinity of Letcher. At Woonsocket a flow of 1,150 gallons per minute is reported from a well 6 inches in diameter. A view of this well is given in Plate XV, which clearly shows that the water is under high pressure, for it is being jetted to a height of over 100 feet above the surface of the ground. The volume of the water varies considerably, but in general increases toward the north. The following is a list of the principal wells in Sanborn County:

Artesian wells in Sanborn County.

	Depth.	Average yield per minute.	Remarks.
	Feet.	*Gallons.*	
T. 105, R. 59	312	.....	Flow from sandstones in Benton group.
	380–476	.....	Flow from Dakota sandstone.
T. 105, R. 60	75–100	.....	Flow from Pleistocene deposits.
	400	.....	Flow from sandstone in the Benton.
	360–630	15–165	Flow from Dakota sandstone; one well has 35-pound pressure.
T. 105, R. 61	250–420	.....	Flow from sandstone in the Benton.
	348–670	4–125	Flow from Dakota sandstone; one well has 80-pound pressure.
Letcher	585	80	Pressure 90-pounds.
T. 105, R. 62	300–410	.....	Small flows from sandstone in the Benton.
	400–490	.....	Small flows from Dakota sandstone.
T. 106, R. 59	80–201	.....	Flow from Pleistocene deposits.
	701–725	.....	Flow from Dakota sandstone.
Artesian	708	120	Do.
T. 106, R. 60	60–118	.....	Flow from Pleistocene deposits.
	580–686	.....	Flow from Dakota sandstone.
T. 106, R. 61	68– 72	.....	Flow from Pleistocene deposits.
	350–373	.....	Flow from sandstone in the Benton.
	560–576	.....	Flow from Dakota sandstone.
T. 107, R. 59	47–110	.....	Flow from Pleistocene deposits.
T. 107, R. 60	70–125	.....	Do.
T. 107, R. 62	689–750	.....	Flow from Dakota sandstone.
Woonsocket	725	1,150	Flow from Dakota sandstone, pressure 130 pounds.
Do	775	Many.	Pressure 125 pounds (mill well).
T. 108, R. 60	74–86	.....	Flow from Pleistocene deposits; one 40-gallon flow.
	530	.....	Flow from sandstone in the Benton.
T. 108, R. 62	792	23	Flow from Dakota sandstone.

Records of some representative wells in this county are as follows:

Record of mill well at Woonsocket.

	Feet.
Yellow and blue clays	0– 25
Sand	25– 45
Blue clay	45– 58
Hardpan	58– 65
Sand	65– 95

ARTESIAN WELL AT WOONSOCKET.

	Feet.
Hardpan and gravel	95–165
Shale with pyrites on top, "soapstone" below	165–412
Hard sandstone on brown sandstone	412–436
Soapstone and shale with pyrites	436–637
Hard lime rock	637–645
Shale	645–690
Hard rock on shale	690–697
Sandstone with water	697–775

Record of well on farm of H. K. and E. O. Ashmore, near Artesian.

	Feet.
Drift	0–130
Chalk rock	130–140
Shale	140–190
Sandstone; no water	190–235
Shale, with first flow at 530 feet; layer of sand rock with water at 630 feet; rock, not very hard, at 690 feet	235–690

Record of well in NW. ¼ sec. 18, T. 106, R. 59.

		Feet.
Glacial deposits		0–130
Chalk	Benton	130–140
Shale		140–200
Sandstone		200–262
Shale. At 525 feet, sandstone with first flow		262–525
Shale		525–626
Sandstone with second flow		626–630
Shale		630–699
Sandstone		699–701

Apparently the first two flows in this well are from the thin sandstones in the Benton group, and, in fact, characteristic Benton fossils were obtained near its bottom.

Record of Ryan well at Letcher.

	Feet.
(?)	1–100
Chalk (Niobrara)	100–170
Sandstone	170–200
Shale	200–300
Sandstone with first flow	300–314
Shale	314–513
Hard sandstone	513–521
Sandstone, with 125-gallon flow	521–561

In this well the Dakota sandstone evidently begins at a depth of 513 feet, and the usual first flow is found in the second sandstone in the Benton at 300 feet. The sandstone at the top of the Benton group at 170 feet did not yield a flow.

Record of city well at Artesian.

	Feet.
Drift deposits	0– 63
Dark shale	63–123
Dark shale with lime rock and pyrites; thin bed of sandstone at base	123–250
Dark shale	250–675
Sandstone, with 50-gallon flow	675–680
Hard sandstone (?)	680–684
Sandstone, with 120-gallon flow	684–708

SPINK COUNTY.

Spink County is in the James River valley and consists mostly of a level plain, with an average altitude of about 1,300 feet, traversed by the shallow valleys of the river and the creeks. The surface is mantled with drift deposits, mostly stratified, but presenting a few morainal hills. The underlying formations are the Pierre, Niobrara, Benton, and Dakota, lying on granite and possibly quartzite in some places. The Niobrara appears to be represented by shale or by chalk so mixed with clay that its distinctive features are not recognized by the well borers. The entire county lies within the Dakota artesian basin, and its waters are tapped by numerous wells, probably 75 in all. They average about 900 feet in depth. Most of them obtain water from the upper portion of the Dakota sandstone, though a few of the deeper ones reach lower strata. The beds lie nearly horizontal but rise slightly to the southeast, owing to the presence of an underground ridge of quartzite and granite which extends across the southeast corner of the county. Some of the wells in the vicinity of this ridge which have not found satisfactory water supplies have been sunk to the granite in the hope of obtaining greater volume. The waters have high pressure, averaging over 100 pounds to the square inch throughout the county, rising to 165 pounds at Mellette and to 177 pounds at Redfield, and diminishing to 50 pounds in the Glidden well, a short distance northwest of Hitchcock, where granite was reached. The principal features of the wells in Spink County are given in the following list:

Artesian wells in Spink County.

Township.	Range.	Depth.	Average yield per minute.	Remarks.
		Feet.	*Gallons.*	
114	62	890–1,000	30–1,000	Pressure 125 and 150 pounds.
114	63	909 and 1,150	550 and 1,200	Pressure 50 pounds.
114	64	921	35	
114	65	940	35	
115	61	1,050	75	Pressure 87 pounds.
116	61	940	.....	
116	62	910–920	35–40	
		895	600	Blaine well, Frankfort.
		1,008	.....	Town well, Frankfort.
116	63	880–923	25–80	
116	64	960–1,060	.....	Redfield city wells Nos. 2 and 3.
116	64	956	300	Institution for feeble-minded.
116	64	858–965	45–175	
		964	1,260	Pressure 177 pounds (Redfield town well).
		1,025	1,900	Well of Hassell & Myers, Redfield.
117	60	897, 957	370, 600	Pressure 122 and 112 pounds (Doland town wells).
117	61	952	110	
117	62	950	350	
117	63	908–1,052	21–45	
117	64	957–987	.....	
117	65	890–955	35–65	
118	60	850–986	25–35	
		920	1,300	Turton town well.
118	61	873–988	35–40	
118	62	863–1,012	25–120	
118	63	870–882	10–200	
118	64	870–1,021	40–160	
		925, 1,003	100, 2,000	Pressure 60 and 150 pounds; Chicago, Milwaukee and St. Paul R. R. well, and mill well at Ashton.
118	65	932, 960	36	Pressure 150 pounds.
119	60	891–925	30–150	Pressure 130 pounds.
119	61	825–970	2–60	
119	62	910–975	26–45	
119	63	920–958	60–894	Pressure 141 and 153 pounds.
119	64	920–1,065	467–1,320	Pressure 156 to 165 pounds (Millette town wells).
119	64	980, 1,020	1,900 and 150	Northville wells.
120	60	960	.....	Well in Conde.
120	62	950–1,170	20–30	
120	63	920	180	
120	64	900–948	12–84	Pressure 120 pounds.
120	65	918	278	

The records of borings in Spink County are very uniform. There are 800 feet or more of shales, representing the Pierre, Niobrara, and Benton formations, the Benton usually containing some thin beds of sandstone and limestone, with small flows. The Dakota sandstone has not been penetrated deeply in the northern portion of the county. At its top there is usually a thick mass of sandstone and in places bodies of shale. In the southern part of the county, where the crystalline rock has been reached, the sandstone was found to be of variable thickness, being about 200 feet thick in the Glidden well, a short distance northwest of Hitchcock, and only 150 feet in the Budlong well, 5 miles northeast of Hitchcock. In both of these places the sandstone occurs in thin layers separated by considerable shale, mostly of light color, in marked contrast to the conditions in other wells not far distant in which thick masses of sandstone were penetrated—for instance, in the boring at Frankfort, which went through 200 feet of sandstone in one nearly continuous mass.

STANDING ROCK INDIAN RESERVATION.

The Standing Rock Indian Reservation is in north-central South Dakota, between the Cheyenne River Reservation and the North Dakota boundary line. It extends from Missouri River westward to longitude 102°. It lies entirely in the valley of Grand River but includes a large area of adjacent slopes. The higher lands consist of the Fox Hills sandstone and overlying lignite-bearing sandstones and shales. The lower lands along Grand River below the mouth of Flint Creek and along the Missouri are underlain by the Pierre shale. This shale has a thickness of about 1,000 feet and is underlain by a regular succession of Niobrara and Benton shales and Dakota sandstone. The Dakota has not been reached by any wells in the vicinity of the reservation but it yields a large flow at the well at Cheyenne Agency, 30 miles to the south, and in the well at Selby, Walworth County. The pressures in these wells indicate that the water in the Dakota sandstone has sufficient head to rise to an altitude of 2,000 feet in the eastern portion of the Standing Rock Reservation, and the gradient is such, as shown on Plate XI, that the altitude of head is probably about 2,300 feet at the southwest corner of the reservation. These factors indicate that flows should be expected along the lower portion of the Grand River valley, all the way across the reservation, and also along Missouri River and for some distance up the adjacent slopes. The depth to the top of the Dakota sandstone is probably about 1,500 feet in the southeast corner of the reservation, but it increases gradually to the north and more rapidly to the west. In the Grand River valley at longitude 102° the depth is probably about 2,500 feet.

STANLEY COUNTY.[a]

Stanley County comprises an area of nearly 5,000 square miles in the central part of South Dakota, extending west from the Missouri River valley south of Cheyenne River, and in its southwestern portion reaching White River. All of it is underlain by the Pierre shale; small areas of the overlying Fox Hills sandstone lie west of Grindstone Buttes and along the eastern margin of the White River formation in badlands in the southwest corner. Under the Pierre shale there is the usual succession of Niobrara chalk, Benton shales, and Dakota sandstone, underlain to the east by granite or quartzite and probably overlapping to the west onto the eastern extension of some of the earlier Mesozoic and Paleozoic rocks that extend underground from the Black Hills region. Under the greater part of this county the beds appear to lie nearly level or to dip gently to the west.

[a] Including northern part of Lower Brule Indian Reservation.

The depth to the Dakota sandstones is about 1,150 feet at Pierre and it gradually increases as the land rises westward. In the northeast corner of the county, at the mouth of Cheyenne River, the depth is probably about 1,250 feet. On this river in the northwest corner of the county the depth is probably nearly 2,000 feet, or possibly more, if there is any unusual thickening of the formations in this direction. In the southwest corner of the county, on White River, the depth is probably somewhat greater and reaches very nearly 2,500 feet, and on the head of Bad River this amount must be considerably exceeded. On the high divide between the rivers the depths are from 300 to 500 feet greater than in the valleys.

To judge by the pressure of the water in the wells at Pierre and the probable increase in head to the west, flowing water may be expected in the large valleys and part way up the slopes all across the county.

Two wells have recently been sunk in this county along the line of the western extension of the Chicago and Northwestern Railway from Pierre. One is at Wendte, 20 miles up the Bad River valley west of Pierre, and the other at Nowlin, 55 miles west of Pierre.

Wendte.—The well at Wendte station is 3 inches in diameter (2 inches at the bottom) and 1,395 feet deep. It yields a flow of 90 gallons a minute and considerable gas comes up with the water, which has a temperature of 108°. The first 1,280 feet were shale with a few strata of limestone in the lower portion, and from 1,280 to 1,395 feet two or three thin strata of sandstone were penetrated. The gas began at a depth of 1,280 feet. This well cost $1,592. An analysis of the water, by G. M. Davidson, is as follows:

Analysis of water from artesian well at Wendte.

[Hypothetical compounds.]	Grains per gallon.
Carbonate of lime	1.68
Carbonate of magnesia	1.13
Oxides of iron and aluminum	.07
Silica	.90
Alkaline chlorides	133.22
Alkaline sulphates	Trace.
Alkaline carbonates	67.93
Total solids	204.93

The water is poor for locomotive use. It will not scale, but will cause foaming.

Nowlin.—The well at Nowlin station is 1,842 feet deep, with a 3-inch casing and 2-inch screen in bottom. It has a flow of 125 gallons a minute, a pressure of about 72 pounds, and a temperature 121°. It passed through 1,770 feet of shale with some limestone, and from 1,770 feet to the bottom was in Dakota sandstone. A small first flow

was found at a depth of about 1,600 feet. Much gas was encountered. The cost was $4,605. The altitude of the well is 1,964 feet and the pressure indicates that the altitude of the head of artesian water in this vicinity is 2,130 feet. Analysis of the water, by G. M. Davidson, is as follows:

Analysis of water from artesian well at Nowlin.

[Hypothetical compounds.]	Grains per gallon.
Carbonate of lime	0.93
Carbonate of magnesia	.25
Oxides of iron and aluminum	.14
Silica	.86
Alkaline chlorides	43.03
Alkaline carbonates	77.98
Total solids	123.19

This is a poor water for boiler use. It will not form scale, but will cause foaming.

SULLY COUNTY.

Sully County extends eastward from Missouri River part way across the high ridges lying between Okobojo and Medicine Knoll creeks. The highlands are covered more or less thickly with glacial drift and the entire region is underlain by a thick mass of Pierre shale. The Dakota sandstone lies deep, even in the Missouri Valley, but has been reached by a number of wells and found to contain large volumes of water having sufficient head to afford a flow throughout the area. The following list indicates the principal conditions under which the waters are obtained:

Artesian wells in Sully County.

	Depth.	Depth to water.	Diameter.	Average yield per minute.	Remarks.
	Feet.	*Feet.*	*Inches.*	*Gallons.*	
Mr. Wadleigh, SE. ¼ sec. 32, T. 113, R. 79.	1,565	1,565	3–2	200	Water saline.
Oneida town well, NW. ¼ sec. 11, T. 114, R. 77.	1,717	1,500 1,630	2	85	Pressure 21 pounds; hard; no gas.
Pearl Township well No. 2, SE. ¼ sec. 3, T. 115, R. 79.	1,645	1,640	2	20	Water soft, warm, gassy.
Pearl Township well No. 1, NW. ¼ NE. ¼ sec. 28, T. 115, R. 79.	1,781	1,600	2	65	Pressure 25 pounds; soft; gassy.
A. Hallam, sec. 19, T. 116, R. 78	1,595	1,595	2	85	Pressure 65 pounds; soft; gassy.

The following records of Sully County wells have been furnished:

Record of deep well in SE. ¼ sec. 32, T. 113, R. 79, Sully County.

	Feet.
Black soil and gravel	0– 2
Yellow clay, gravelly	2– 30
Blue clay, part till	30– 190
Blue shale, with slabs	190– 610
Black shale, with some slabs	610– 680
Coarse gravel	680– 720
Shale (?)	720– 783
Very hard sandstone, with gas	783– 785
Blue shale, with "shells" of limestone	785–1,000
Gray shale	1,000–1,060
Blue shale, with some limestone and slate	1,060–1,400
Hard stone	1,400–1,402
Shale and sandy streaks, with first flow at 1,402 feet	1,402–1,510
Fine sand rock, with hard shells; second flow, gas	1,510–1,565

Record of deep well in NW. ¼ sec. 11, T. 114, R. 77, Oneida.

	Feet.
Black soil	0– 3
Yellow clay	3– 34
Blue clay and gravel pockets	34– 170
Blue shale, with hard shells	170– 950
Black shale, with slate	950–1,200
Gray shale	1,200–1,260
Blue shale	1,260–1,400
Shale, sandy streaks	1,400–1,560
Sandstone, with a few hard "shells;" first flow	1,560–1,630
Sand rock; second flow	1,630–1,717

Record of well No. 1, Pearl Township, Sully County.

	Feet.
Black soil	0– 3
Yellow clay	3– 34
Blue clay	34– 210
Blue shale, with slabs 2 to 20 feet thick	210– 968
Shaly limestone	968– 970
Shale	970–1,020
Limestone	1,020–1,028
Shale	1,028–1,080
Blue shale, streaks of gray shale, and limestone	1,080–1,585
Sandstone; water, flows not definite	1,585–1,780
Very hard rock	1,780–1,781

Record of deep well No. 2, Pearl Township, Sully County.

	Feet.
Black soil	0 – 1½
Yellow clay	1½– 32
Blue clay (till and Pierre?)	32 – 200
Sand	200 – 210
Shale, with hard layers	210 –1,240
"Many hard layers of limestone"	1,240 –1,265

	Feet.
Hard cap rock	1,265 –1,295
Shale, with few "shells" (i. e., hard streaks, some gray below, blue and black above)	1,295 –1,525
Sandstone and water; no flow	1,525 –1,531
Alternating shale and sand rock, 5 to 10 foot layers; water	1,531 –1,600
Sandstone and flow of water, with gas	1,600 –1,645
Very hard stone; probably granite	1,645 –1,646

TURNER COUNTY.

Turner County comprises a portion of the Vermilion River valley and the adjoining prairies to the summit of Turkey Ridge. Its surface is mostly covered with glacial drift, which lies in thick masses on the higher lands. The Sioux quartzite rises in the northern and northeastern portions of the county, where it is exposed at a number of points and reached by numerous wells of moderate depth. To the south the drift is underlain by the Niobrara chalkstone and probably by more or less Pierre shale in Turkey Ridge. The Benton group and Dakota sandstone underlie the central and southern portions of the county and abut against the slope of Sioux quartzite, the edge of the younger formations probably extending for several miles northwestward beyond the margin of the Dakota.

Owing to the diminished pressure of water in the Dakota sandstone, artesian flows from this source are available in this county only in the southeast corner of the Vermilion River valley. There are, however, at numerous localities small flows from the base of the drift at depths mostly of 50 to 100 feet. A number of deep wells which have been sunk in Turner County have found in the Dakota sandstone water that rises several hundred feet, but not sufficiently to flow. One well 4 miles west by south of Hurley has a depth of 513 feet, passing through drift to 80 feet; chalkstone from 80 to 150 feet; Benton shales from 150 to 417 feet; and Dakota sandstone to the bottom, which apparently is in Sioux quartzite. A well at Hurley passes through 35 feet of drift, 100 feet of chalk rock, and 265 feet of Benton to the top of the Dakota sandstone. North of this place are a number of moderately deep wells that apparently obtain water supplies from sandstone at the base of the chalk rock, which is underlain at no great depth by the Sioux quartzite.

UNION COUNTY.

The Dakota sandstone appears to underlie all of Union County, outcropping to the southeast in the bluffs on the Iowa side, near the mouth of Big Sioux River. The sandstone has been reached by a number of wells of moderate depth in the western portion of the county, but the head of the artesian water is so low that there are no surface flows.

An unsuccessful deep boring at Elk Point had the following record:

Record of deep boring at Elk Point.

	Feet.
Loamy clay	0– 20
Quicksand and good water	20– 21
Clay	21– 51
Sand; irony water	51– 61
Clay	61–101
Sand and gravel (water)	101–111
Shale (Graneros)	111–115
Shale and sandstones	115–330
Sandstone	330–460
Shale; some sand	460–545
Hard white rock (limestone?)	545–560

The Dakota sandstone probably extends about 200 to 545 feet in this well.

WALWORTH COUNTY.

Walworth County extends eastward from Missouri River and, except for a narrow strip of bottom land, consists of highlands with altitudes of 1,800 feet to slightly over 2,000 feet. The altitude of the river bottom is about 1,500 feet, being 1,552 feet at Evarts. The county is underlain by the Dakota sandstone, which has an altitude above sea level of about 300 feet in the eastern part and 150 feet in the western part.

A well recently sunk at Selby reached the Dakota sandstone at a depth of 1,747 feet, penetrated it to a depth of 1,897 feet, and obtained a flow of 17 gallons per minute, under sufficient pressure to rise about 38 feet above the surface, or to 1,915 feet above sea level. The first 90 feet in the well are glacial drift, below which are 1,662 feet of shales, comprising the Pierre, Niobrara, and Benton. The diameter of the well is $1\frac{1}{4}$ inches inside. The water is alkaline and tepid, and contains sufficient gas to afford a constant flame several feet high. The principal flow was from a depth of 1,880 feet. This well indicates that artesian waters are available in Walworth County up to altitudes slightly above 1,900 feet in the vicinity of Selby, with the head diminishing somewhat to the east, as indicated by the lower pressure at Ipswich, and increasing to the south, as shown by the head of 1,974 feet in the Gettysburg well, in the adjoining county. These facts would indicate that about half of Walworth County is sufficiently low for a flow; the ridge north of Swan Creek, between Selby and Byron, and some smaller areas are too high for flowing wells.

YANKTON COUNTY.

Yankton County extends northward from Missouri River into a region of rolling plains traversed by the valley of James River. The higher lands are covered by glacial drift and the underlying forma-

tions appear only in bluffs along Missouri River. Nearly all of the area is underlain by the Niobrara chalkstone, but this formation is cut through by the Missouri below the mouth of the James, revealing the underlying Carlile shale of the Benton group. The entire county is underlain by the Dakota sandstone, which contains a large volume of water under pressure sufficient to afford flowing wells in all the townships except on the divide between James River and Clay Creek and in the northeast corner of the county. Along the bottom lands of Missouri and James rivers these waters have been developed by numerous wells which obtain flows at moderate depths. There is considerable variation in the volume of water, one well in Yankton 493 feet deep having at one time produced 3,000 gallons per minute from an 8-inch casing, while others in other portions of the district yield very much less, owing to locally increased compactness of the water-bearing rock and diminution of pressure. The decrease of pressure is gradual and regular from west to east across this county, owing to the fall of hydraulic head toward the zone of leakage in the area in which the Dakota sandstone is at or near the surface in Union County and farther south. The following list gives the principal features of the deeper wells in this county from which reports have been received:

Artesian wells in Yankton County.

Township.	Range.	Depth.	Average yield per minute.	Remarks.
		Feet.	*Gallons.*	
93	54	250–450	6–120	Pressure 10 to 60 pounds.
93	55	212–483	36–140	Pressure 15 to 30 pounds.
		520, 521	95, 350	Pressure 45 to 49 pounds; several flows.
		493	3,000	Excelsior Mill, Yankton; 8-inch; several flows; pressure 52 pounds.
		595	1,450	Fountain Roller Mill, Yankton; 6-inch; pressure 48 pounds.
		625	880	City well, Yankton; 6-inch; pressure 18 pounds.
		942	.....	City well, deepened; no additional flow.
93	55–56	672	165	Asylum well near Yankton.
		524	2,600	College Hill, Yankton; 2-inch well.
		500	1,300	Cement company's well, near Yankton; 5 flows; 5-inch well; pressure 50 pounds.
		521	350	Whiting Nursery, Yankton; 3-inch well; pressure 49 pounds.
		400–475	6–95	Small wells.
93	57	530, 585	Many.	Pressure 30 pounds or more.
94	54	268–510	5–150	Numerous small wells; pressure 12 to 60 pounds.
94	55	435–648	3–100	
95	54	545, 580	8	Three flows; pressure 6 pounds.
95	55	535–554	Many.	Several flows.
		266	90	First flow.
95	56	544–640	43–80	Pressure 15 pounds.
96	55	145–590	Several.	
96	56	700	Many.	No flow.
96	57	505	5	Two flows.

One of the noticeable features in this table is the great variation in the volume of water in wells in the vicinity of Yankton. This is particularly shown by the relatively small volume afforded by the

Yankton city well. In order to obtain a larger supply, this well was deepened some years ago from 625 to 942 feet, but no material increase of flow was obtained. It is stated that the last 44 feet were in crystalline "bed rock." In all the deeper wells several flows are found in sandstone beds occurring at intervals in alternation with clay beds in the Dakota. The thickness and position of these sandstone strata appear to be very variable. In general the deeper seated waters are more uniform in volume and furnish large supplies, mainly in Yankton and vicinity. Water for local use is found at higher horizons in many small wells, which are sunk only sufficiently deep to reach a moderate supply.

In Yankton the waters are used to a considerable extent for power in mills, in some wells developing a pressure of 50 pounds to the square inch. The wells of the higher lands are considerably more than 600 feet deep; those on the lowlands near the river are of correspondingly less depth. The pressure varies, partly on account of differences of altitude in the wells, but gradually decreases toward the east, as above explained. It is claimed that the pressure in the wells is diminishing, and as a very large amount of water has been flowing from them for many years doubtless this is the case in portions of the area where wells are numerous. At one of the mills in Yankton the original pressure was 45 pounds, but after the water had been flowing freely for two years it was found to be losing pressure. The practice of shutting off the flow when the mill was not running was then begun, since when the pressure has remained constant at 37 pounds. The apparent diminution of pressure in many of the wells is due to the caving in of the lower portion, which cuts off the lower and stronger flows, and in some it is due also to the fact that the pipes are corroded and permit the water to escape underground into strata where the pressure is less.

The geologic conditions in the wells of Yankton County are very similar to those of Bonhomme County, most of the borings beginning in the Niobrara chalk rock, passing into the Benton group at a depth of 50 to 200 feet, and going through 300 feet of this group to the Dakota sandstone. Some typical sections are as follows:

Record of city well at Yankton.

	Feet.
Yellow clay	0– 25
Blue clay	25– 55
Chalk	55–115
Clays, Benton	115–415
Alternations of sandstone and clay, the latter predominating	415–615
Principal water-bearing horizon	615–625
Alternations of sandstone and clay	625–898
"Granite"	898–942

70214—IRR 227—09——10

In the asylum well, 3 miles north of the city, a very similar record was observed, with a large body of water-bearing sand extending from 609 to 672 feet. It is stated that in another well at the asylum the Sioux quartzite was reached at a depth of 825 feet. At the mill well in Yankton a somewhat different series of beds was reported as the following record shows:

Record of mill well, Yankton.

	Feet.
Soil, sand, and gravel	0– 38
Chalk	38–100
Shale	100–126
Hard rock	126–130
Sand	130–164
Shale	164–229
Sand	229–254
Shale	254–389
Sand and clay in alternating strata	389–489
Water-bearing sandstone yielding a flow of 1,450 gallons per minute through a 6-inch casing, with a surface pressure of 48 pounds to the square inch	489–595

It is probable that the sand beds reported between 130 and 254 feet occur in the other wells in this vicinity but were not reported. The upper sand stratum is probably the one that usually occurs a short distance below the Niobrara chalkstone, and the hard-rock stratum is doubtless a concretion such as characterizes the upper portion of the Carlile shale.

At the Yankton cement works, west of Yankton, the Dakota sandstone appears to have been reached at a depth of 450 feet and penetrated for 50 feet, yielding a flow of 1,300 gallons per minute through a 5-inch casing.

THE CONSTRUCTION AND MANAGEMENT OF ARTESIAN WELLS.

A number of artesian wells in South Dakota which found abundant water supplies have since so deteriorated as to be of no further use. This has led many persons to believe that the life of such a well is necessarily short, and that the expense of renewing borings and casings would be so large that in the end deep wells could never be economical. It has not been supposed, of course, that all wells would soon give out, but the possibility has been thought to introduce a very great element of risk into well ownership. In the investigation here reported special attention was given to this particular point, and wherever a well had given out an effort was made to ascertain the causes and whether they could have been avoided. Reliable or definite statements were difficult to procure, but enough was learned to show that in no case of failure was it inevitable from natural causes that the well should have become unserviceable if it had been

properly built or suitably managed. The principal cause of failure was found to be the clogging up of the well with sand, clay, and other materials from below, which finally cut off the flow or reduced it to so small an amount that the well was no longer used. Another difficulty was the escape of water around the outside of the pipe in such manner that the flow of the well could no longer be controlled. Under such conditions the water would run to waste and in all probability the well would clog itself up.

Well boring is a mechanical art which has been practiced for so many years and by so many ingenious persons that it has reached a high stage of development. As in all other industries, a large number of skilled artisans are engaged in the business, as well as, on the other hand, many incompetent persons, whose methods are crude. It would be impossible to say to what extent the failures of certain wells are due to the lack of necessary knowledge of well boring on the part of their constructors or to conditions which, at the time, could not have been foreseen. Many of the earlier wells were bored by men who were not at that time particularly skillful in their art, but who have since become expert to a high degree; but it is cause for regret that even now wells are occasionally sunk by men with whom the success or failure of a well is largely a matter of chance. Very few persons for whom wells are bored know what is going on underground or are adequate judges of the merits of the well borer. They must trust very largely to the reputation of the well borer or to the recommendations which he brings, and should, of course, endeavor to procure an experienced and skillful man rather than a cheap contract to be executed by a borer of whose success there is doubt. There are, however, a few features of well boring that can be pointed out in such a manner as to aid persons planning to sink wells, and at the same time afford to well borers some knowledge that has proved serviceable in other regions where the art of well boring is highly developed.

In the first place, the enormous pressure, which the underground waters possess in most of the wells, must be borne in mind. This pressure is, in many wells, 500 pounds per square inch at the depth at which the water is struck. Strong casings, properly built machinery, and expert men are absolutely essential to cope with such pressures. The mere operation of boring to a depth of 500 to 1,000 feet or more is relatively simple, and its principle is presumably familiar to nearly all persons who have any interest in wells. A heavy iron rod with a steel bit on its end is dropped a few feet at the rate of 20 to 40 strokes per minute, in such a manner as to break off and churn up the material which is to be penetrated. As the hole is made, pipe for its casing is passed down, more or less closely following the bit, particularly if the boring is in soft materials, where casing is always necessary to hold up the walls. The pipe is lowered or gently forced down length upon length, each new length being screwed tightly into

the coupling of the preceding one, until the water is reached. The churned-up material is either forced out by a stream of water that is pumped into the boring under considerable pressure, or baled out by a sand bucket—a short length of pipe with a large upward-opening valve in its bottom. It often happens that the casing will reach a certain point and go no farther; then a smaller size of pipe must be introduced, and in some wells it has been found necessary to decrease the size of the pipe several times before reaching the water.

With some of the improved machinery now in use this change in the size of the casing is not necessary so often as formerly, but it is expedient to make it to a certain extent for a reason that will now be explained. It is always desirable to have the casing of a well doubled for the greater part of its depth—that is, to have an outer pipe extending nearly to the water, and then to have an inner pipe extending to and into the water-bearing bed. The advantages of this arrangement are manifold, but the principal advantage is that when the inner pipe becomes in any way out of order, it may be easily withdrawn, repaired, and reinserted or replaced by a new pipe. The inner pipe will receive all the wear from suspended sand, etc., as well as the greater part of the corrosion from the water. These last two factors are not so important as might be imagined, and the life of a good, heavy pipe, particularly if it is galvanized, is exceedingly long. The principal difficulties occur at the lower end of the pipe, and it is for these mainly that it is desirable to have the inner pipe removable. It is very important to have the outer pipe rigidly fixed at its lower end in a hard bed, so that no water may reach the surface along its outer side. In a number of wells the waters have begun seeping up around the outer casing until they have finally made sufficient space to emerge in large volumes, and after that occurs the life of a well is usually soon terminated. In other wells the water has seeped up along the outer side of the well casing and found its way, in whole or in part, into some higher porous stratum, so as to decrease or totally lose its head and volume. A relation of this character is shown in figure 7.

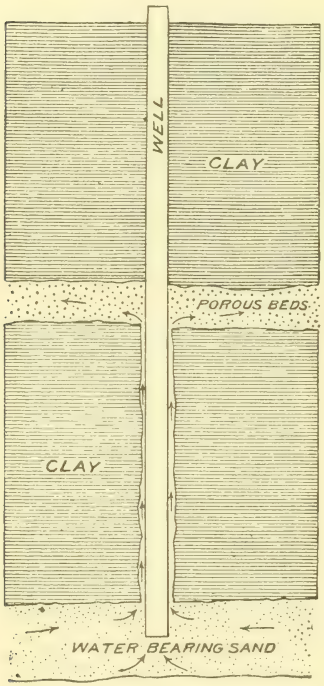


FIG. 7.—Diagram illustrating the escape of waters from a lower into a higher porous stratum along the outer side of the casing in an artesian well.

This is probably the reason that the pressure in numerous wells is so much less than would be expected from the depth and experience

of wells in the surrounding district. In many wells, some of which have failed and others of which, owing to exceptionally favorable conditions, are now working satisfactorily, the casing delivering the water reaches through the cap rock but has no great extension into the water-bearing beds nor any anchorage except the thin layer of cap rock. This is a dangerous feature, and has caused clogging or displacement in a number of wells. It is always much safer to sink the inner pipe entirely through the water-bearing beds to some hard stratum lying next below them, and then sufficiently far into that stratum to hold the pipe rigidly. As it is necessary for the portion of the pipe that is in the water-bearing beds to be perforated, to admit the water, it is further desirable that this portion should be of extra heavy piping, to much more than compensate for the weakness caused by the perforations. It must be acknowledged that there is often great difficulty in managing the completion of the well after a great volume of water has been struck, but it is believed that a skillful well borer can properly insert the perforated pipe or strainer and anchor it firmly in the bed rock below. The difficulties of working in water having a high pressure are very great, and the well may be damaging itself during the delay incident to its final completion; but there are now so many expedients known to the skillful well borer that he surmounts most of these difficulties with relative ease.

It is very important in constructing and managing a well to prevent the discharge of any large volume of solid matter from the water-bearing beds, for this has been the cause of the clogging up of the greater number of wells which are now unserviceable. The perforated pipe usually obviates the possibility of extensive discharges of solid matter if the perforations are sufficiently small and if the pipe is anchored at its bottom in a hard stratum at the base of the water-bearing beds. If such an anchorage can not be made, it is advisable to introduce a valve at the open end of the pipe, although it will require no small degree of skill to insert and close a valve of this character. The condition which probably ensues when a well discharges considerable quantities of solid matter is the development of a large cavity at the lower end of the casing, and eventually the shale roof of this cavity may cave in and seal off the water-bearing bed. In wells that are not constructed with perforated pipe having its lower end securely anchored in some firm bed lying beneath the water-bearing material, as here recommended, it will be found safer never to let the well have its full flow when it shows any disposition to throw sand or other matter. On the other hand, it is desirable not to shut a well off entirely, because more or less sand is apt to be forced up into the casing and become so set that further flow is completely shut off.

INDEX.

A.

Page.

Aberdeen, wells at 73
wells at, record of 41
rocks in 39, 40, 41, 50, 55
Albert well, record of 112
Alexandria, rocks near 34–35
Algonkian rocks, character and distribution of 33–40
Andover, wells at 90, 91
wells at, record of 91
rocks in 50, 56
Archean rocks, character and distribution of 33–40
Ardmore, well at 100
Argentine, well at 94, 100–101
well at, water of, analysis of 101
Argyle, rocks at 24, 25
Arikaree formation, character and distribution of 27, 31, 32
Arlington, well at 116
well at, record of 116
rocks in 38
Artesian, well near, record of 135–136
well near, rocks in 44
Artesian flows, explanation of 7
See also Flows; Wells.
Asmuss well, record of 68
Aurora County, geology of 65
wells in 66–67
records of 67, 68
rocks of 44–45, 51, 55

B.

Bad River, rocks near 24, 26
Bartow well, record of 45
Battle Creek, rocks near 14, 21
Beadle County, geology of 68–69
wells in 69
rocks in 43, 55
Bear Butte Canyon, rocks in, view of 14
Beaver Creek, rocks in 14
Bed rock. *See* Sioux quartzite.
Belle Fourche, rocks near 20–22
wells near, records of 78–81
Belle Fourche River, rocks in 24
Benton group, character and distribution of 9, 20–22, 27, 48–53
section of 51
waters of 62
Big Badlands, rocks of 27
view in 26, 28
Bighorn Mountains, section of, plate showing 8
Big Sioux River, rocks on and near 49, 53
Bigstone Lake, rocks at 52
Bijou Hills, rocks of 58
Black Earth Creek, rocks near 34

Page.

Black Hills, description of 8–9
section of 9–10
figures showing 8, 59
water horizons in, figure showing 59
See also Waters, underground.
Black Hills region, geology of 8–26
geology of, general relations 8–10
Bohri well, rocks in 39
section of 43
Bonhomme County, geology of 69
wells in 70–72
records of 71–72
rocks in 47, 51, 54
Bowdle Hills, rocks on 58
Bridgewater, rocks near 34
Brookings, well at 72
well at, rocks in 38
Brookings County, geology of 72
wells of 72
Brooks well, record of 115
Brown County, geology of 72
rocks in 57
wells in 73
Brown Valley, well in, rocks of 39
Brule clay, character and distribution of 9, 24–25, 27
views of 26, 28
Brule County, geology of 74
wells in 74–75
records of 75
rocks in 47
Brule Creek, rocks on 54
Budlong well, rocks in 38
section of 42
Buffalo County, geology of 75–76
wells in 76
record of 76
rocks in 51
Buffalo Gap, rocks near 15, 16, 17, 18, 19
section near 22
wells at 88–89
Butte County, geology of 76–77
wells in 77–81
records of 78–81

C.

Cambria, coal near 18
Cambrian rocks, character and distribution of 10–11
Campbell County, geology of 81
wells in 81
Capa, well at 120–121
well at, rocks in 26
water of, analysis of 121
Carboniferous rocks, character and distribution of 10, 11–15
Carlile shale, character and distribution of 9, 21–22
sections of 22

Page.

Carthage, wells at, rocks in 51
Cascade Springs, rocks near 15, 16, 18, 19
Castalia, well near, rocks in 47, 55
Castle Rock, rocks of 31, 32
Cave Hills, lignite at, view of 30
  rocks of 31
  section near 28–29
Cedar Draw, view in 26
Chadron formation, character and distribution of 9, 24–25, 27
  view of 26
  waters of 63–64
Chamberlain, wells at 119–120
  wells at, record of 75
    rocks in 47
Chambers Ranch, well on, record of 81
Charles Mix County, geology of 82
  wells in 82–84
    records of 51, 83–84
    rocks in 47, 55
Cheyenne Agency, well at 84–85
  well at, record of 85
Cheyenne Indian Reservation, geology of 84
  wells of 84–85
    records of 85
Cheyenne River, rocks on 18–19, 21, 24, 26, 27
  sections of, on and near 19, 22
Clark, wells at 86
Clark County, geology of 85
  wells in 85–86
    record of 86
    rocks in 43
Clay County, geology of 86–87
  wells in 87
Clay Creek, rocks on 54
Coal measures, section of 30
Codington Co., geology of 87
Cold Brook, rocks on 14
Columnar sections, figures showing 8, 59
Cottonwood Draw, rocks on 28
  view at 28
Cretaceous rocks, character and distribution of 10, 17–24, 41–58
Cross sections of South Dakota, plate showing 24
Crow Creek, well at, rocks in 51
Crow Creek Agency, well at 76
  well at, record of 76
Custer, rocks near 12
Custer County, geology of 87–88
  wells of 88–89

D.

Dakota sandstone, character and distribution of 9, 20, 40, 41–48
  sections of 42–48
  structure map of 66
    explanation of 41
  waters of 61–62
Davison County, geology of 89–90
  wells in 89–90
    rocks in 44, 50, 54, 55, 56
Dawson Creek, rocks near 54
Day County, geology of 90
  rocks in 57
  wells of 90–91
    record of 91

Page.

Deadwood, rocks near 11
  rocks near, plate showing 10
Deadwood sandstone, character and distribution of 10–11
  view of 10
  waters of 63
Deers Ears, rocks of 30, 31
De Smet, well at 43, 116
  well at, record of 44, 116
    rocks in 37–38
Deuel County, geology of 92
Dikes occurrence of 34
Dougan well, record of 45
Douglas County, geology of 92
  wells of 92–93
    rocks in 37, 51, 55
Drainage, outline of 8
Draper, well at 121
Dry Creek, rocks on 20
Durst well, record of 79

E.

Edgemont, rocks near 18, 20, 21, 24, 25–26
  rocks near, view of 20
  wells near 94, 95–99
    record of 95–98
    water of, analysis of 99
Edmunds County, geology of 93
  wells of 93
Elevations, range of 8
Elk Creek, rocks on 12
Elk Mountain, rocks near 15
Enemy Creek, rocks on 35, 49–50, 54
Englewood limestone, character and distribution of 10, 12
Ethan, wells at and near, rocks in 44, 50–51

F.

Fairburn, rocks near 10, 15, 24, 25
Fall River, rocks on 18, 19
Fall River County, geology of 94
  section across, figure showing 94
  wells in 94–101
    records of 95–98, 100
Faulk County, geology of 101
  wells in 101–102
    record of 102
    rocks in 47–48
Faulkton Hills, rocks on 58
Fiestner well, record of 113
Firesteel Creek, rocks on 49, 50, 54
Flint Creek, rocks on 28
Flows, area of 64–65
  area of, map showing ..... Pocket.
  volume of, plate showing 64
Forest City, rocks near 58
Fort Meade, rocks near 16
  well at 125–126
    record of 125–126
Fort Randall, well at, record of 104
Fort Union formation, character and distribution of 26–31
Fossils, occurrence of 18, 20, 21, 22, 23, 28, 31, 48, 49, 52–53, 58
Fox Hill sandstone, character and distribution 9, 24, 27, 28–31, 58
  waters of 63

Page.
Frankfort, well at, section of..... 42
French Creek, rocks on..... 14,21
Fulton, rocks near..... 35
Fuson Creek, rocks on..... 19–20,25
Fuson formation, character and distribution of..... 9,19–20,41
section of..... 19

G.

Garden, rocks near..... 26
Geography, description of..... 8
Gettysburg, well at, rocks in..... 48
Glidden well, rocks in..... 38,50
section of..... 42
Grand River, rocks on..... 30
Graneros shale, character and distribution of..... 9,20–21
view of..... 20
Grant County, geology of..... 102
wells in..... 102–103
rocks in..... 52,56
Great Plains, description of..... 8
Greenhorn limestone, character and distribution of..... 9,21
view of..... 20
Greenwood, well at, record of..... 83–84
Gregory County, geology of..... 103
wells of..... 103–104
record of..... 104
Groton, rocks near..... 57
Gypsum, character and distribution of..... 15–16

H.

Hamlin County, geology of..... 104
Hand County, geology of..... 104
wells of..... 104–105
record of..... 105
Hanson County, geology of..... 106
map of..... 106
underground ridge in..... 34
wells in..... 106–107
record of..... 107
rocks in..... 50
Harrold, well at, record of..... 109
Hartville uplift, section of, plate showing..... 8
Hay Creek, rocks near..... 18,20
Hayden, F. V., on geology of region..... 27
Haystack Butte, rocks of..... 31
Hermosa, rocks near..... 14,15,16,17,18,20,23,24
rocks near, view of..... 14
Hetland, well at, record of..... 117
Highmore, well at..... 141
well at, record of..... 111
Hitchcock, wells near, rocks in..... 38,50
Hot Springs, rocks near..... 13,14,16,17,18,19
section near..... 19
well at..... 101
Hughes County, geology of..... 108
wells at..... 108–109
record of..... 108,109
rocks in..... 48
Hurley, wells at and near..... 142
rocks in..... 46,51,54
Huron, well at, record of..... 43
Hutchinson County, geology of..... 109
wells in..... 109–111
record of..... 110–111
rocks in..... 45–46,51,54

Page.
Hyde County, geology of..... 111
wells of..... 111
record of..... 111
Hydraulic grade, explanation of..... 60–61
figures showing..... 60,61
Hydrology, meaning of term..... 7

I.

Ipswich, wells at..... 93
Iroquois, well at..... 114–115
well at, record of..... 114
rocks in..... 38

J.

James River, rocks near..... 35,49,50,53–54,56–57
section of, showing hydraulic gradient..... 61
Jerauld County, geology of..... 112
wells in..... 112–113
records of..... 112–113
rocks in..... 50
Johnson Creek, rocks near..... 35
Jurassic rocks, character and distribution of..... 10,16–17,41

K.

Kennebec, wells at..... 121
Keyapaha River, rocks on..... 26
Kimball, well at, rocks in..... 47
Kingsbury County, geology of..... 113
wells in..... 113–117
records of..... 114–117
rocks in..... 55
Knapp well, record of..... 107
Koto Hills, rocks of..... 58

L.

Lake Andes, wells at, records of..... 51,83
Lake County, geology of..... 117
wells of..... 118
Lakota sandstone, character and distribution of..... 9,18,41
view of..... 10
Lame Johnny Creek, rocks on..... 24,25
Laramie formation, occurrence of..... 27,28–31
Laramie Range, section of, plate showing..... 8
Lawrence County, geology of..... 118
wells of..... 118
Lead, rocks near..... 26
Leonard, A. G., on geology of region..... 30–31
Letcher, rocks near..... 53
well near..... 135
record of..... 135
rocks in..... 44,55
Lignite, occurrence of..... 18
view of..... 30
Lincoln County, geology of..... 118–119
Lyman County, geology..... 119
wells of..... 119–121
record of..... 120
water of, analysis of..... 120

M.

McClure well..... 120
record of..... 120
McCook County, geology of..... 122
wells of..... 122
McPherson County, geology of..... 122
wells of..... 122–123
Madison, wells at..... 118
wells at, rocks in..... 37,118

Page.
Map, artesian, of South Dakota ..... Pocket.
showing volume of flows 64
Map, bed-rock contour, of South Dakota 32
Map, geologic, of South Dakota ..... Pocket.
Map, structural, of Dakota sandstone 66
Marshall, Minn., wells near, rocks in 52
Marshall County, geology of 123
wells of 123
Matthew, W. D., on Rosebud formation 27
Meade County, geology of 124
wells of 124–126
records of 125–126
Metamynodon sandstone, character and distribution of 27
Milbank, rocks at 49
wells at, rocks in 39, 52
Miner County, geology of 126
wells of 126–127
rocks in 51, 55
Minnehaha County, geology of 127
wells of 127
Minnekahta, rocks near 24, 25
well at 99–100
record of 100
Minnekahta Junction, well at 38
Minnekahta limestone, character and distribution of 10, 14–15
view of 14
Minnelusa sandstone, character and distribution of 10, 13–14
view of 14
waters of 62–63
Minnewaste limestone, character and distribution of 9, 18–19
Mississippian rocks, character and distribution of 10, 13, 14
Missouri River, rocks on 26, 49, 56
Mitchell, rocks near 33, 37
wells at and near 89
rocks in 34, 44
view of 134
Montrose, rocks near 34
Moody County, geology of 127
wells of 127–128
record of 128
Morrison shale, character and distribution of 9, 17–18, 41
Mount Vernon, well at 89
well, record of 44
Mowry shale, character and distribution of 21
Murdo McKenzie, well at 121

N.

Newcastle, rocks near 20
Niobrara formation, character and distribution of 9, 22, 26, 53–56
Niobrara River, rocks on 53
Nowlin, well at 139–140
well at, rocks in 26
water of, analysis of 140

O.

Oelrichs, rocks near 23, 24
Oneida, well at, record of 141
Opeche formation, character and distribution of 10, 14
Ordovician rocks, character and distribution of 10, 11
Oreodon beds. *See* Brule clay.
Orient, well near, record of 102
Orman well, rocks in 80
water of, analysis of 80
Ortonville, rocks near 39
Owl River, rocks on 24, 28

P.

Pahaspa limestone, character and distribution of 10, 12–13
Parker, rocks near 34
Parkston, wells at, rocks in 45–46
Pennington County, geology of 128
rocks of 12
wells of 128
Pennsylvanian rocks, character and distribution of 10, 14
Permian rocks, character and distribution of 10, 14, 15
Pierpoint, well at 90, 91
Pierre, wells at, record of 48
wells at, rocks in 40
Pierre Creek, rocks on 34, 35
Pierre shale, character and distribution of 9, 22–24, 26, 27, 28, 56–58
Pine Ridge Reservation, geology of 128–130
wells of 129–130
Pipestone, rocks near 33, 34
Pipestone clay, character and distribution of 34
Plankinton, rocks near 53
wells at and near 44, 68
record of 68
rocks in 44–45
Ponca, Nebr., well at, rocks in 39, 40
Post-Eocene rocks, character and distribution of 31–32
Potter County, geology of 130
wells in 130
record of 130
rocks in 48
Pringle, rocks near 24
Protoceras sandstone, character and distribution of 27
view of 28
Pukwana, well at, record of 75
Purple limestone. *See* Minnekahta limestone.

Q.

Quaternary deposits, character and distribution of 58

R.

Raesley well, record of 67
Rapid, rocks near 12, 17, 20
wells near 128
Rapid Creek, rocks on 10, 24
Raymond, wells at and near 85
well at and near, records of 43, 85
Reagan, A. B., on Rosebud Reservation 27
Ree Heights, rocks at 57
Resley well, record of 45
Roberts County, geology 131
wells of 131
Rock Creek, rocks near 35

Page.
Rockerville, rocks near ... 25
Rockport, rocks near ... 35
Rosebud, well at, rocks in ... 26
Rosebud member, occurrence of ... 27
Rosebud Reservation, geology of ... 131
well on ... 131–133
rocks in ... 48
record of ... 132
Ryan well, record of ... 67

S.

Salem, rocks near ... 34
Sanborn County, geology of ... 133
wells in ... 133–136
records of ... 135–136
rocks in ... 44, 55
Schmidt well, record of ... 113
Scotland, well at ... 70–71
well at, record of ... 47, 51, 71–72
rocks in ... 54
Selby, well at ... 143
Sheep Mountain, view of ... 28
Shelby, well at ... 93
Sheps Canyon, rocks near ... 16, 17
view in ... 10
Short Pine Hills, rocks of ... 30, 31
Sioux City, Iowa, rocks at ... 49
wells at, rocks in ... 39–40
Sioux Falls, well at, rocks in ... 34, 37
Sioux quartzite, character and distribution of ... 33–34
surface of, map showing ... 32
wells to ... 35–36
Slim Buttes, rocks of ... 26, 30, 31
sections at ... 31, 32
South Dakota, map of, showing hydraulic contours ... 61
South Dakota, eastern, geology of ... 32–58
section of, figure showing ... 59
structure of ... 32–33
water horizons in, figure showing ... 59
See also Waters, underground.
South Dakota, northwestern, explorations in ... 27
geology of ... 27–32
South Dakota, south-central, geology of ... 26–27
Spear well, record of ... 115
Spearfish, rocks near ... 16
wells near ... 118
Spearfish Creek, rocks on ... 12–13
Spearfish formation, character and distribution of ... 9, 15–16
Spencer, rocks near ... 34
Spink County, geology of ... 136
wells of ... 136–137
rocks in ... 42, 50, 55, 137
Split Rock Creek, rocks on ... 34, 54
Spring Creek, rocks near ... 13, 14, 21, 25
Springfield, well near ... 70
well near, rocks in ... 47, 51, 54
Squaw Creek, rocks on ... 20
Standing Rock Reservation, geology of ... 138
wells of ... 138
Stanley County, geology of ... 138–139
wells of ... 139–140
water of, analyses of ... 139, 140
Storla well, record of ... 45
Streams, seepage from ... 7

Page.
Sturgis, rocks near ... 16, 20, 23
view of ... 14
wells near ... 124–125
record of ... 125
Sully County, geology of ... 140
wells of ... 140–142
records of ... 141–142
Sundance formation, character and distribution of ... 9, 16–17
Susie Peak, rocks of ... 21
Swan Creek, rocks on ... 58
Swan Lake, rocks at ... 57

T.

Tepee buttes, distribution and character of ... 23
Tertiary rocks, character and distribution of ... 9, 24–27, 58
section of ... 32
The Dells, rocks near ... 34
Titanotherium beds. *See* Chadron formation.
Todd, J. E., on geology of region ... 28, 48, 52, 58
Thunder Creek, rocks on ... 28
Topography, description of ... 8
Trent, well at, rocks in ... 58
Triassic rocks, character and distribution of ... 9, 15–16
Tripp, well at, record of ... 110–111
well at, rocks in ... 46, 51, 54–55
Turkey Ridge, rocks of ... 53, 54
Turner County, geology of ... 142
wells in ... 142
rocks of ... 46, 51
Turtle Ridge, rocks of ... 57
Twelvemile Creek, rocks on ... 49–50, 54

U.

Underground ridge, location and character of ... 33, 37–40
Union County, geology of ... 142
wells of ... 143
record of ... 143
Unkpapa sandstone, character and distribution of ... 9, 17
view of ... 10

V.

Vermillion River, rocks on ... 34
Vivian, well at ... 121
Volcanic ash, occurrence of ... 26

W.

Walworth County, geology of ... 143
wells of ... 143
Wasta, well near ... 128
Waters, underground, discussion of ... 59–149
discussion of, by counties ... 65–149
escape of ... 148–149
figures showing ... 148
horizons of, descriptions of ... 61–64
figures showing ... 59
source and movement of ... 7, 60
Webster, well at ... 91
Well boring, methods of ... 147–148
Wells, description of, by counties ... 65–149
general discussion of ... 64–65

Page.
Wells, artesian, construction and management 146–149
distribution, of, map showing ..... Pocket.
pressures in 147
Wells, flowing, area of 64–65
area of, map showing ..... Pocket.
necessary depth of 65
volume of, map showing 64
Wells to quartzite, list of 35–36
Wendte, well at 139
well at, water of, analysis of 139
White Lake, well at, rocks in 45
White River, rocks near 24–26, 27
White River group, character and distribution of 9, 24–26, 27, 29, 31, 32
section of 31
views of 28, 30
Whiterock, well at, rocks in 52
Whitewood Canyon, rocks in 11
Whitewood limestone, character and distribution of 10, 11
Wildcat Gulch, view of 14
Willis, Bailey, on geology of region 28
Willow Creek, rocks on 23
Winchell, N. H., on geology of region 27, 34
Wolf Creek, rocks near 34, 54
Wolsey, well at, record of 42
well at, rocks in 38
Woonsocket, well at 134–135
well at, record of 134–135
rocks in 44, 55
view of 134
Wounded Knee Creek, rocks on, view of 30

Y.

Yankton, rocks near 53, 57
wells at 145–146
wells at, records of 46, 145–146
rocks in 39, 51–52
Yankton Agency, well at, record of 83–84
Yankton County, geology of 143–144
rocks in 57
wells in 46, 144–146
record of 46, 145, 146
rocks in 54

O

U. S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

WATER SUPPLY PAPER 3[illegible]

Topography compiled from U. S. Geological Survey maps with [illegible] data mostly [illegible] and other [illegible] to date

GEOLOGIC MAP OF SOUTH DAKOTA

BY N. H. DARTON

Scale [illegible] 40 miles

Contour [illegible] 250 feet, and [illegible]

1909

MAP OF SOUTH DAKOTA, SHOWING THE ARTESIAN CONDITIONS

By N. H. Darton

1908

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

WATER-SUPPLY PAPER 228

WATER-SUPPLY INVESTIGATIONS

IN THE

YUKON-TANANA REGION, ALASKA

1907 AND 1908

FAIRBANKS, CIRCLE, AND RAMPART DISTRICTS

BY

C. C. COVERT AND C. E. ELLSWORTH

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CONTENTS.

	Page.
Introduction	7
Scope of work	7
Cooperation	9
Explanation of data and methods	9
General description of area	12
Conditions affecting water supply	15
General conditions	15
Melting of frozen ground	15
Precipitation	17
The Fairbanks district	19
Description of area	19
Gaging stations	20
Little Chena River drainage basin	22
General description	22
Little Chena River above Elliott Creek	23
Little Chena River below Fish Creek	24
Elliott Creek above Sorrels Creek	25
Sorrels Creek	26
Fish Creek above Fairbanks Creek	27
Fish Creek at mouth	29
Bear Creek	30
Fairbanks Creek	30
Miller Creek	30
Chatanika River drainage basin	32
General description	32
Chatanika River near Faith Creek	33
Chatanika River below Poker Creek	34
McManus Creek	36
Faith Creek	38
Kokomo Creek	39
Poker Creek	39
Cleary Creek	40
Eldorado Creek	40
Dome Creek	41
Miscellaneous measurements	41
Goldstream Creek drainage basin	42
General description	42
Goldstream Creek at claim 6 below	43
Pedro Creek	44
Fox Creek	44
Washington Creek drainage basin	45
General description	45
Washington Creek above Aggie Creek	45
Washington Creek below Aggie Creek	46
Aggie Creek at mouth	48

The Fairbanks district—Continued. Page.
Beaver Creek drainage basin 49
General description 49
Measurements 50
The Circle district 51
Description of area 51
Gaging stations 52
Birch Creek drainage basin 53
General description 53
Birch Creek at Fourteenmile House 53
North Fork of Birch Creek 54
Harrison Creek 55
Crooked Creek 56
Mammoth Creek 56
Porcupine Creek 57
Boulder Creek 58
Deadwood Creek 59
The Rampart district 59
Description of area 59
Gaging stations 61
Minook Creek drainage basin 62
General description 62
Minook Creek above Little Minook Creek 63
Granite Creek 64
Chapman Creek 64
Slate Creek 65
Ruby Creek 65
Hoosier Creek 65
Little Minook Junior Creek 66
Little Minook Creek 66
Hunter Creek 68
Miscellaneous measurements 69
Troublesome Creek drainage basin 69
General description 69
Troublesome Creek below Quail Creek 70
Miscellaneous measurements 71
Minor Yukon River drainage 71
Russian Creek 71
Squaw Creek 71
West Fork of Tolovana River drainage basin 71
Description 71
Measurements 72
Baker Creek drainage basin 72
General description 72
Baker Creek at road crossing 73
Allen Creek 73
New York Creek at Thanksgiving ditch intake 74
California Creek at Thanksgiving ditch intake 75
Thanksgiving ditch near outlet 76
California Creek branch of Thanksgiving ditch near intake 77
Eureka Creek 78
Pioneer Creek 79
Hutlinana Creek 80
Miscellaneous measurements 82

The Rampart district—Continued. Page.
Patterson Creek drainage basin 83
Fiftymile River at White Horse 84
Comparative discharge of different areas 84
Hydraulic development 90
Ditch and pipe lines in Alaska 90
Fairbanks district 92
General conditions 92
Proposed ditch lines 93
Water power 94
Circle district 95
General conditions 95
Eagle Creek 95
Porcupine Creek 95
Rampart district 96
General conditions 96
Minook Creek group 96
General conditions 96
Hunter Creek 97
Little Minook Creek 97
Hoosier Creek 97
Baker Creek group 97
General conditions 97
What Cheer Bar ditch 98
Eureka Creek 98
Thanksgiving ditch 98
Sullivan Creek ditch 98
Water power for electric transmission 99
Storage and conservation 101
Index 105

ILLUSTRATIONS.

Page.
PLATE I. *A*, Price current meters; *B*, Measuring Grand Central River 10
II. Map showing location of gaging stations in Fairbanks district 20
III. Mining operations on Cleary Creek 40
IV. Map showing location of gaging stations in Circle district 52
V. Map showing location of gaging stations in Rampart district 60
VI. *A*, Hydraulicking on Eagle Creek; *B*, Hydraulic elevator on Hoosier Creek 94
VII. *A*, Shoveling in on Thanksgiving Creek; *B*, Splash dam in operation on Little Minook Creek 96
FIGURE 1. Index map showing location of quadrangles in Yukon-Tanana region 13
2. Diagram showing flows of Chatanika and Little Chena rivers 17
3. Diagram showing mean weekly discharge in second-feet of streams in Yukon-Tanana region, 1908 85

WATER-SUPPLY INVESTIGATIONS IN THE YUKON-TANANA REGION, ALASKA, 1907 AND 1908.

By C. C. Covert and C. E. Ellsworth.

INTRODUCTION.

SCOPE OF WORK.

For a number of years the United States Geological Survey has made systematic measurements and studies of water supply as one of the great resources of the country. The data thus obtained are now available for many of the more important streams in the United States and are extensively used by engineers and others in problems involving water power, city water supply, irrigation, and manufacturing.

The development of the important placer-mining fields of Alaska, notably those of Seward Peninsula and the Yukon-Tanana region, is intimately associated with the successful utilization of their water supplies. A knowledge of the amount of water available in the streams would have prevented most of the failures that have been made in the past, and will be invaluable in connection with future development.

A strong tendency exists in Alaskan development work to push forward the construction of ditches before making sure of that primary requisite of their successful operation—an adequate water supply. The results of such a policy were shown during the summers of 1907 and 1908 in portions of the Yukon-Tanana region and in Seward Peninsula, where severe local droughts caused much loss and inconvenience to mining operators. As these conditions may not prove to be exceptional in any portion of the larger placer districts of Alaska, too much stress can not be laid on the importance of stream-flow data. Except during the low-water period, which ordinarily lasts only a part of the season, the water supply is sufficient; but in combination with other unfavorable conditions—the shortness of the season, the frozen ground, the distance from base of supplies, and the consequent high cost of transportation—a reduction of even two or three weeks in the working season may mean the difference between profit and loss.

Hydraulic developments are most advanced in the Nome region of Seward Peninsula, which has been an important producer of placer gold since 1899, and in which hundreds of miles of mining ditches have been built at great expense. Similar developments proposed for the Yukon-Tanana region should now be given careful consideration.

For this reason stream-measurement work, like that begun in the Nome region in 1906, was undertaken in the Yukon-Tanana region in 1907 by C. C. Covert, who was in the field from June 18 to September 23 of that year. During the season of 1908 the work was continued by Mr. Covert and C. E. Ellsworth. In March, 1908, Mr. Covert went to the Fairbanks district to gather data on the spring run-off from the melting snow, and later in the season he extended the work to the Circle and Rampart districts. In June Mr. Ellsworth and Mr. Covert met at Circle and made a reconnaissance trip across country to Fairbanks. On August 1 Mr. Ellsworth went to the Rampart district, where he continued the work until the middle of September. Mr. Covert and the rest of the party remained in the Fairbanks district until the end of August, when they made the return trip to Circle, arriving there September 15. Much credit for the amount of data obtained and the extended territory which the party was able to cover is due to George Neuner, jr., field assistant, who made many of the measurements, and Charles E. Anderson, who acted as cook and packer.

The work in the Yukon-Tanana region in 1907 was largely of a reconnaissance character, but a few regular gaging stations were established. In 1908 the work was continued along lines similar to those followed in the previous year, but the records cover a longer period (May 1 to October 15), and the area under investigation included about 4,200 square miles. Daily records were kept at a few regular stations established at convenient points in the different drainage basins, and miscellaneous measurements were made in the surrounding country. This plan afforded the best opportunities for procuring comparative data. In this region, where water storage is lacking, daily records are highly important, but are very difficult to obtain. Outside of the placer mining creeks the country is practically a wilderness, where it is almost impossible to get observations other than those made during the occasional visits of the engineer. In some localities daily or even weekly records could not have been assured, and the results obtained from occasional measurements would have furnished no comprehensive idea of the daily run-off of the streams throughout the open season.

The work of collecting the data and preparing this report was done under the direction of the water resources branch by the engineers detailed for the purpose. The expenses were paid out of the appro-

priation for investigating the mineral resources of Alaska, and the field work has been under the general supervision of Alfred H. Brooks, geologist in charge of Alaskan work.

COOPERATION.

The funds available for the work were inadequate for the thorough investigation of the region concerning which it was desirable to procure records. It was possible to obtain daily gage readings only through the cooperation of mining operators, ditch companies, and others. Special acknowledgment for such cooperation is due to Mr. John Zug, superintendent of the Good Roads Commission; Mr. C. W. McConaughy, chief engineer of the Chatanika Ditch Company; Mr. Falcon Joslin, president of the Tanana Valley Railroad Company; Mr. Herman Wobber, Fairbanks Creek; Mr. Martin Harrais, Chena Lumber and Light Company, Chena; Mr. W. H. Parsons, general manager Washington-Alaska Bank; Mr. Frank G. Manley, Baker Hot Springs; Mr. A. V. Thorns, general manager Manley Mines; Mr. M. E. Koonce, Rampart; and to the many individual miners who are personally interested in the work.

EXPLANATION OF DATA AND METHODS.

The methods of carrying on the work and collecting the data were essentially the same as those previously used for similar work,[a] but were adapted to the special conditions found in Alaska.

In the consideration of industrial or mining enterprises which use the water of streams it is necessary to know the total amount of water flowing in the stream, the daily distribution of the flow, and facts in regard to the conditions affecting the flow. Several terms are used—such as second-foot, miner's inch, gallons per minute, etc.—to describe the quantity of water flowing in a stream, the one selected depending on the use to be made of the data.

"Second-foot" is in most general use for all classes of work, and from it the quantity expressed in other terms may be obtained. It is an abbreviation of cubic foot per second, and may be defined as the quantity of water flowing per second in a stream 1 foot wide and 1 foot deep at the rate of 1 foot per second. It should be noted that it is a *rate* of flow, and to obtain the actual quantity of water it is necessary to multiply it by the time.

"Second-feet per square mile" is the average number of cubic feet of water flowing per second from each square mile of area drained, on the assumption that the run-off is distributed uniformly, as regards both time and area.

"Run-off in inches" is the depth to which the drainage area would be covered if all the water flowing from it in a given period were con-

[a] See Water-Supply Papers U. S. Geol. Survey, Nos. 94, 95, and 201.

served and uniformly distributed on the surface. It is used for comparing run-off with rainfall, which is expressed in depth in inches.

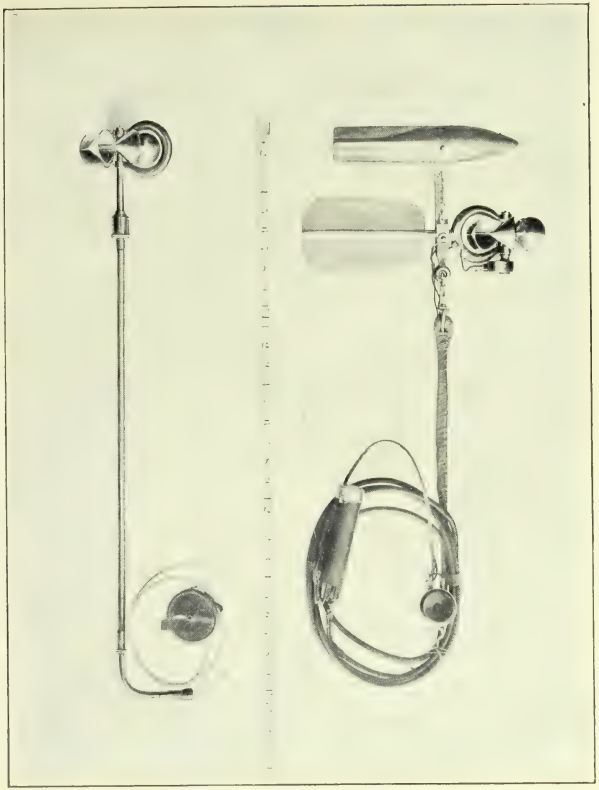
"Acre-foot" is equivalent to 43,560 cubic feet, and is the quantity required to cover an acre to the depth of 1 foot. It is commonly used in connection with storage problems.

The "miner's inch," the unit used in connection with placer mining, also expresses a rate of flow, and is the quantity of water flowing through an orifice of a given size with a given head. The head and size of the orifice used in different localities vary, thus making it a most indefinite and unsatisfactory unit. Owing to the confusion arising from its use it has been defined by law in several States. The California miner's inch is in most common use in the United States, and was defined by an act approved March 23, 1901, as follows: "The standard miner's inch of water shall be equivalent or equal to 1½ cubic feet of water per minute, measured through any aperture or orifice." This miner's inch corresponds to the so-called "6-inch pressure," and is one-fortieth of a second-foot.

A list of convenient equivalents for use in hydraulic computations is given below:

1 second-foot equals 40 California miner's inches (law of March 23, 1901).
1 second-foot equals 50 "old California" miner's inches (used prior to law of March 23, 1901).
1 second-foot equals 7.48 United States gallons per second; equals 448.8 gallons per minute; equals 646,272 gallons for one day.
1 second-foot for one year covers 1 square mile 1.131 feet, or 13,572 inches deep.
1 second-foot equals about 1 acre-inch per hour.
1 second-foot for one day covers 1-square mile 0.03719 inch deep.
1 second-foot for one day equals 1.983 acre-feet.
100 California miner's inches equal 15.7 United States gallons per second.
100 California miner's inches for one day equal 4.96 acre-feet.
100 United States gallons per minute equal 0.223 second-foot.
100 United States gallons per minute for one day equal 0.442 acre-foot.
1,000,000 United States gallons per day equal 1.55 second-feet.
1,000,000 United States gallons equal 3.07 acre-feet.
1,000,000 cubic feet equal 22.95 acre-feet.
1 acre-foot equals 325,850 gallons.
1 inch deep on 1 square mile equals 2,323,200 cubic feet.
1 inch deep on 1 square mile equals 0.0737 second-foot per year.
1 mile equals 5,280 feet.
1 acre equals 43,560 square feet.
1 acre equals 209 feet square, nearly.
1 cubic foot equals 7.48 gallons.
1 cubic foot of water weighs 62.5 pounds.
1 horsepower equals 550 foot-pounds per second.
1 horsepower equals 746 watts.
1 horsepower equals 1 second-foot falling 8.80 feet.
1⅓ horsepower equals about 1 kilowatt.

To calculate water power quickly: $\frac{\text{Sec. ft.} \times \text{fall in feet}}{11}$ = net horsepower on waterwheel realizing 80 per cent of theoretical power.



A. PRICE CURRENT METERS.

B. MEASURING GRAND CENTRAL RIVER.

The determination of the quantity of water flowing past a certain section of a stream at a given time is termed a "discharge measurement." The quantity is the product of two factors—the mean velocity and the area of the cross section. The mean velocity is a function of surface slope, wetted perimeter, roughness of bed, and the channel conditions at, above, and below the gaging section. The area depends on the contour of the bed and the fluctuations of the surface. The two principal ways of measuring the velocity of a stream are by floats and current meters.

All measurements by the engineers of the Survey were made with the current meter; but as float measurements can readily be made by the prospector the method is described below.

The floats in common use are the surface, subsurface, and tube or rod floats. A corked bottle with a flag in the top and weighted at the bottom makes one of the most satisfactory surface floats, as it is affected but little by wind. In flood measurements good results can be obtained by observing the velocity of floating cakes of ice or débris. In all surface-float measurements the observed velocity must be multiplied by 0.85 to 0.90 to reduce it to the mean velocity. The subsurface and tube or rod floats are intended to give directly the mean velocity in the vertical. Tubes give excellent results when the channel conditions are good, as in canals.

In measuring velocity by a float, observation is made of the time taken by the float to pass over the "run"—a selected stretch of river from 50 to 200 feet long. In each discharge measurement a large number of velocity determinations are made at different points across the stream, and from these observations the mean velocity for the whole section is determined.

The area used in float measurements is the mean of the areas at the two ends of the run and at several intermediate sections.

The essential parts of the current meters in use are (1) a wheel of some type so constructed that the impact of flowing water causes it to revolve and (2) a device for recording or indicating the number of revolutions. The relation between the velocity of the moving water and the revolutions of the wheel is determined for each meter. This rating is done by drawing the meter through still water for a given distance at different speeds and noting the number of revolutions for each run. From these data a rating table is prepared, which gives the velocity per second for any number of revolutions. Many kinds of current meters have been constructed.

The small Price acoustic meter (Pl. I, *A*) was used exclusively in the work in Alaska. Measurements were made by wading, except on Chatanika River near Faith Creek and Little Chena River below mouth of Fish Creek, where a cable and car were installed for use during high stages, and on Birch Creek at Fourteenmile House, where the government ferry was utilized.

In making a measurement a tape line is stretched across the stream (Pl. I, *B*) and depth and velocity are measured at regular intervals (1 foot to 5 feet, depending on the size of the stream). The depths from which the area of the cross section is computed are taken by soundings with a graduated rod. The velocities are measured by a current meter.

Two methods of measuring the velocity were used. In the first the meter is held at the depth of the thread of mean velocity, which has been shown by extensive experiments to occur at about 0.6 of the total depth. In the second method the mean of the velocities taken at 0.2 and 0.8 depth is used. This method is not adapted to very shallow streams or to those with extremely rough beds.

One of the general laws of the flow of streams with permanent cross sections is that the discharge varies directly with the stage of the water, or the gage height, and that it will be the same whenever the stage or gage height is the same. Therefore, in order to determine the daily discharge of a stream, a gage on which the fluctuations of the surface of the stream may be noted is installed and read daily. As the discharge regularly increases with the stage, it is possible with a few discharge measurements taken at various stages to construct a rating curve which will give the discharge at all stages. The beds of most of the streams measured changed but little during the season and it was therefore possible to obtain the daily flow, as just stated.

GENERAL DESCRIPTION OF AREA.

The section of Alaska lying between the Yukon and Tanana rivers and reaching from their confluence to the international boundary, about 300 miles to the east, is known as the Yukon-Tanana region. It embraces about 40,000 square miles, of which about 4,200 are considered in this report. The gold placers of the Fortymile, Birch Creek, Rampart, and Fairbanks districts are situated in this region, and their economic importance has led the Geological Survey to devote several years to the work of making topographic and geologic maps of the area, and, in 1907 and 1908, to make a study of the water supply of a portion of the territory covered by the Circle, Fairbanks, and Rampart quadrangles. The location of the quadrangles surveyed in the Yukon-Tanana region and of the quadrangles in which lie the drainage areas of the streams studied is shown in the index map, figure 1.

Gold was discovered in the Fortymile district in 1886 and in the Birch Creek and Rampart districts in 1893, but not until the discoveries in the Klondike in 1896 did the rapid development of the interior of Alaska begin and Circle and Rampart become supply points for the mining camps along the Yukon. The Fairbanks dis-

trict was brought into prominence by the discoveries in 1902, and it has since become the largest placer mining district in Alaska. The chief topographic features of the country, the absence of any well-defined divide separating the Yukon-Tanana drainages, and the irregular arrangement of the streams that make up the drainage systems of this region are clearly shown on the published maps (see fig. 1) which, except the Fortymile, are issued with bulletins[a] only.

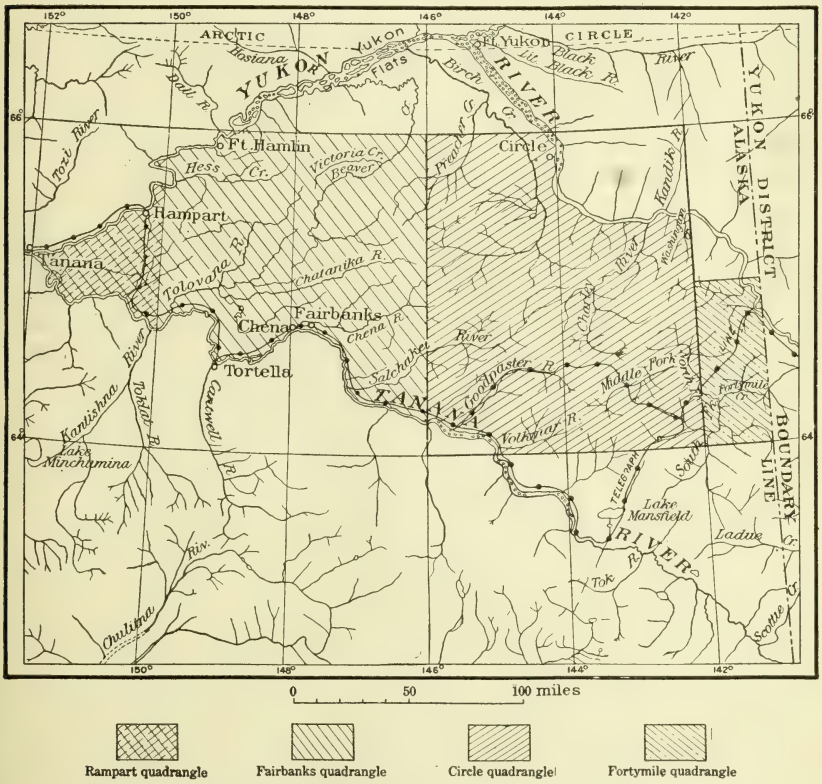


FIGURE 1.—Index map showing location of quadrangles in Yukon-Tanana region.

These drainage systems hold remarkably close relations. The headwaters of the larger streams interlock with one another, their numerous ramifying branches taking so many different directions that the traveler, unless provided with maps and compass, is often led astray by the similar even-topped ridges that separate the drain-

[a] Prindle, L. M., The gold placers of the Fortymile, Birch Creek, and Fairbanks regions: Bull. U. S. Geol. Survey No. 251, 1905.

Topographic map, Fortymile quadrangle; scale, 1:250000; by E. C. Barnard, U. S. Geol. Survey, 1905. For sale at 5 cents a copy or $3 a hundred.

Prindle, L. M., The Yukon-Tanana region, Alaska; description of the Circle quadrangle: Bull. U. S. Geol. Survey No. 295, 1906.

Prindle, L. M., Hess, F. L., and Covert, C. C., The Yukon-Tanana region, Alaska; description of the Fairbanks and Rampart quadrangles: Bull. U. S. Geol. Survey No. 337, 1908.

ages of the headwaters of perhaps three or four different streams, which radiate from some one point, but belong to different drainage areas.

The most important streams tributary to the Yukon are Fortymile and Seventymile creeks, Charley River, and Birch and Beaver creeks; those tributary to the Tanana are the Volkmar, Goodpaster, Salcha, Chena, and Tolovna rivers. Besides these major streams many small tributaries, such as Minook and Baker creeks, are important, because they are the sites of large mining operations.

The entire area except the higher ridges was once well timbered, but the forests are fast disappearing before the woodman's ax and forest fires—a fact most deplorable for the future of the country.

The climate and vegetation of the Yukon-Tanana region have been described by Prindle[a] as follows:

> The temperature has a wide range of variation. Temperatures below 80° F. below zero have been reported, and those 90° or more above zero are not uncommon. The extreme continued cold of winter leaves so deep an impress that the streams become covered with a layer of ice 6 feet thick, which in places lingers till late in summer, and the ground remains for the most part permanently frozen. The long days of summer, often very warm, soon mantle with green luxuriance much of the deeply frozen surface, and the shadows of the ice-scarred spruces along the river banks become enlivened with patches of grass or glow with brilliant fire weed and clumps of roses. This extreme differentiation of the seasons entails much change in mode of living and methods of transportation, and the times at which the gradual change takes place from summer to winter and winter to summer are therefore the most important climatic periods of the year. The Yukon at Circle closes about the middle of October, soon after the mush ice begins to run, and opens again about the middle of May, when the breaking of the ice emphasizes most dramatically the advent of the open season.
>
> While the winters are in general similar in their essential characteristics, the summers vary greatly in temperature and rainfall. Some of them are characterized by long periods of beautiful weather with many days of great heat during June and July and the early part of August. The occasional thunderstorms or rainy days furnish insufficient water to meet the demands of mining, and work is thus frequently brought almost to a standstill. In other seasons thunderstorms may be of almost daily occurrence for several weeks. A third season may be unusually wet with frequent cold rains accompanied by snow in the higher hills.
>
> The snowfall is generally light, and the total precipitation is much less than that of the southeast coast. The lowlands are comparatively free from frost during the latter part of June and the months of July and August, and ordinarily mining can be carried on from the middle of June to the middle of September, and in a favorable season may be continued much longer.

It should be added that the region is characterized by wide local variations in rainfall during the summer months.

Transportation facilities are of vital importance to the future development of this region. During the open season, from June to October, steamers ply up and down the Yukon; during the winter

[a] Prindle, L. M., The Yukon-Tanana region Alaska; description of the Circle quadrangle: Bull. U. S. Geol. Survey No. 295, 1906.

travelers must follow the trails from Valdez or White Horse. While travel, either in winter or summer, is so slow, tedious, and expensive, development on a large scale will require enormous expenditures of both time and money; and the region can not be economically and completely developed until it can be reached by rail from the seacoast towns. Most of the mining camps using Fairbanks for their base of supplies are readily reached by either steam or wagon road, or both. From Circle, Rampart, and the other supply points the camps are reached by wagon or pack train over trails that are difficult, especially in wet weather.

The Alaska Road Commission is doing much to facilitate development by constructing wagon roads which make it feasible to deliver the heavy machinery that is absolutely essential to the economic working of the mines and that can not be handled by pack trains.

CONDITIONS AFFECTING WATER SUPPLY.

GENERAL CONDITIONS.

Water for mining purposes in the Yukon-Tanana region is drawn entirely from the normal flow of the streams at the point of supply. During the sluicing period, which usually extends from about May 20 to September 10, the daily flow is derived from three sources—the slow melting of snow and ice accumulated chiefly in the form of "winter glaciers" at the heads of the streams, the melting of ground ice and frozen earth, and the summer rains. Very little of the snow melts and runs off before the spring break-up, which in this district begins about the middle of April. The winter run-off, especially in the upper basins, accumulates with the ice and snow in the stream beds. The rise in the streams begins about the middle of May and continues intermittently until about May 30, when the maximum discharge occurs, but ice and snow do not entirely disappear before the middle or last of July. Mr. A. D. Gassaway, of the Chatanika Ditch Company, estimated the maximum flow of Chatanika River near the mouth of Faith Creek at about 1,250 second-feet in 1907, and stated that this discharge occurred about May 30. After that date the flow gradually decreased until the minimum stage was reached, about July 10. In 1908 the maximum discharge occurred from May 20 to 25, and was about 1,340 second-feet, while the minimum discharge of 82 second-feet was recorded July 20 and 21.

MELTING OF FROZEN GROUND.

The melting of frozen ground affords a slight additional supply of water to the streams. On the northern slopes and in the deep canyons which are protected from the rays of the sun, the ground never thaws more than a few inches, even during July and August, when the

sun shines nearly twenty-four hours a day; but on the southern slopes and in the lowlands the imprisoned moisture is liberated through the combined influence of abundant sunshine and occasional warm rains. This gradual thawing of the frozen ground serves to increase the minimum flow during a low-water period, as in the season of 1908. (See fig. 3, p. 85.) The only natural storage for rainfall in this country is that afforded by the ubiquitous moss, which absorbs much of the moisture that otherwise would quickly pass beyond use, and distributes the melting of the ground ice over a longer period; but, on the other hand, to a certain extent, it prevents the ground from thawing during the summer and thus does away with any natural underground storage. This covering is saturated from ground thaw, and consequently any rainfall flows off the steep slopes very quickly and finds its way to the streams, causing them to rise and fall rapidly. (See fig. 2.) Because of this lack of ground storage the streams depend largely on rainfall for their supply after the snow and ice have disappeared in the spring break-up.

PRECIPITATION.

Precipitation records kept at Fairbanks since 1905 show that snowfall in this section amounts to about 40 inches. In connection with its investigations of stream flow the Geological Survey established four precipitation stations in the Yukon-Tanana region in 1907 and three in 1908. All records are kept by voluntary observers. The names and locations of these stations, the names of observers, and the dates of establishment are given in the following table:

Rainfall stations in Yukon-Tanana region.

Station.	Letter on Pls. II, IV, and V.	Latitude.	Longitude.	Elevation in feet—		Observer.	Date established.
				Above sea level.	Above ground.		
Baker Hot Springs	T	64° 58′	150° 40′	370	3	V. L. Bevington	Aug. 5, 1908
Charity Creek	N	65° 24′	146° 16′	2,800	3	H. R. Burke	
Cleary	K	65° 05′	147° 26′	1,000	4	Charles Sinclair	June 25, 1907
Eagle Creek	R	65° 26′	145° 27′	2,590	3	A. R. Garner	July 7, 1908
Faith Creek	M	65° 17′	146° 23′	1,400	4	M. T. Kerrick	July 1, 1907
Poker Creek	L	65° 08′	147° 28′	750	5	G. M. Sabean	Aug. 3, 1907
Summit Roadhouse	H	65° 02′	147° 26′	2,310	3	Mrs. Annie M. Walsh.	July 3, 1907

The table following gives the monthly precipitation at points in the Yukon-Tanana region for 1907 and 1908. Records for earlier years have been given by Abbe[a] and by the writer in a previous report.[b]

[a] Abbe, Cleveland, jr., Geography and geology of Alaska: Prof. Paper U. S. Geol. Survey No. 45, 1906, pp. 189–200.

[b] Henshaw, F. F., and Covert, C. C., Water-supply investigations in Alaska, 1906–1907: Water-Supply Paper U. S. Geol. Survey No. 218, 1908, pp. 139–149.

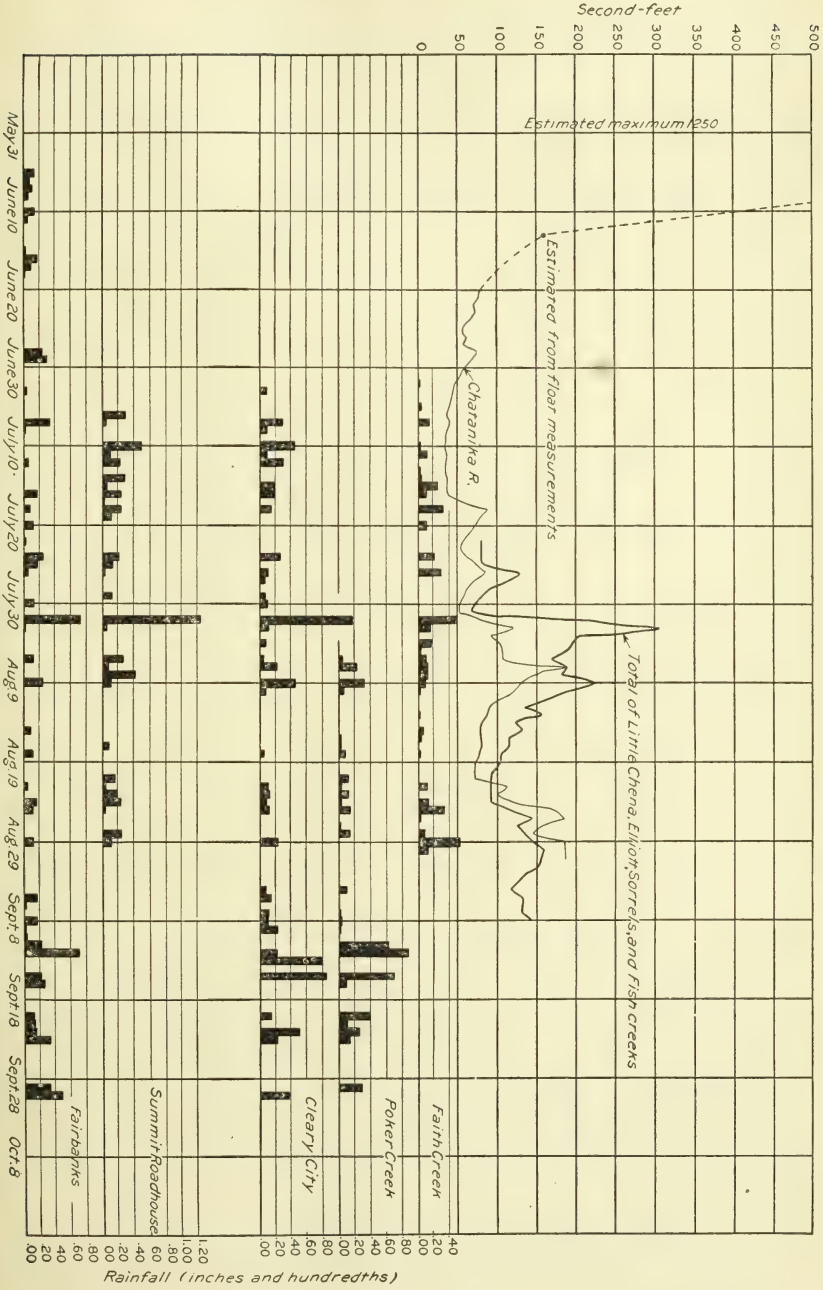


FIGURE 2.—Diagram showing flow of Chatanika River and total flow of Little Chena River and its tributaries in 1907.

Monthly precipitation, in inches, at stations in Yukon-Tanana region, 1907–1908.

[Rainfall or melted snow is given in the first line; snowfall in the second line.]

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Baker Hot Springs, 1908										0.41	0.20		
										4.1	2.0		
Circle, 1907	1.02	0.57	0.28	0.15	0.29		1.30	2.79	1.73			0.63	
	8.5	7.8	3.25									8.2	
Circle, 1908	1.23	.25	.76	1.45	.29	0.20	.87	1.08	2.21	.40	.75		
	9.2	2.5	6.75	8.0						3.0	8.5		
Charity Creek, 1908				.11	.27	1.33	2.80	2.33	2.28	.20			
										3.0			
Cleary, 1907						.84	2.55	2.88	3.82				
Eagle Creek, 1908								2.99					
Fairbanks, 1907	3.30	.86	2.42	.03	.35	1.47	1.51	1.81	3.58	2.44	.35	.59	18.71
	33.0	8.6	24.2	.3						24.4	3.5	5.9	99.9
Fairbanks, 1908	.42	.21	1.1	.11	.52	.96	.73	.71	.15	.47	.51		
	4.2	2.1	11.0	.8					1.53		4.0		
Faith Creek, 1907							1.87	3.00	2.97				
Fort Egbert, 1907	1.45	.21	.75	.25	.40	1.89	1.48	1.98	1.45	1.12	.40		
	2.0	2.0	7.5	.15	.55					13.0	4.0		
Fort Egbert, 1908	.12	.25	.75	.10		2.16	2.47	1.02	1.48	.18	.82		
	3.0	2.5	7.5	1.0						6.0	7.0		
Fort Gibbon, 1907	1.26		.53	0	.30		2.58	2.31	2.32	1.22	.03		
	12.6		5.0						4.00	12.0	1.5		
Fort Gibbon, 1908	.23	.26	.90	0	1.16		.96	1.13	1.60	.45			
	4.0	6.0	17.0	0					[a] 2.25	6.0			
Kechumstuk, 1907	.12	.20	.27	Tr.	1.30	2.30	1.00	2.14	.49	.72	.40		
	2.0	3.0	4.0		12.0					9.0	4.0		
Kechumstuk, 1908	0	0	.41	.40	1.78	1.77	2.30	2.22	1.35				
			5.0	4.0									
North Fork, 1907	.69	.28	.27	Tr.	1.34	1.92	1.57	3.19	2.00	1.40	.20		
	15.5	3.0	3.0		4.0				5.0	12.0	2.0		
North Fork, 1908	.50												
	5.0	Tr.											
Poker Creek, 1907								1.40	3.70	1.70	.25	1.07	
										24.0	3.3	6.8	
Poker Creek, 1908		1.32		.42	.58	1.80	2.02	.99	2.45	.75			
		10.5		5.0					4.5	6.9			
Rampart, 1907	1.17	.44	1.17	.02	.44	1.64	2.29	3.38	2.52	.65	.55		
	12.0	4.5	12.8	2.5							6.3		
Rampart, 1908	1.08	.52	.81	.58	.82	1.38	1.13	.46	1.56	.39			
	11.5	6.9	8.1							5.1			
Summit Roadhouse, 1907							2.71	3.27	[a] 3.33				

[a] September 1–22.

Precipitation records for May to August, inclusive, at various points in the Yukon-Tanana region, may be summarized as follows:

Summary of precipitation in Yukon-Tanana region.

Station.	Maximum.		Minimum.		Mean.	Duration of records.
	Inches.	Year.	Inches.	Year.	Inches.	
Fairbanks	5.73	1906	2.92	1908	4.60	1906–1908
Circle	4.15	1907	2.44	1908	3.30	1907–1908
Rampart	7.75	1907	3.79	1908	5.58	1905–1908
Fort Egbert	6.31	1908	4.87	1906	5.75	1903, 1905–1908
Fort Gibbon	10.26	1905	3.30	1904	5.76	1903–1908
Kechumstuk	9.06	1906	3.66	1905	6.73	1904–1908

The table above shows that a total precipitation as high as 10.26 inches and as low as 2.44 inches has occurred during the mining season.

A comparison of the records of rainfall in 1907 throughout Alaska with records previously obtained shows that the season was nearly

normal, especially in the interior; but the records of 1908 indicate that in the Fairbanks, Circle, and Rampart precincts, except in a small area at the head of Chatanika, Twelvemile, and Preacher creeks the precipitation was below the normal, while in Kechumstuk and Fort Egbert it was somewhat above the usual amount.

May, June, and July are invariably months of slight rainfall in the interior, and the streams soon reach a very low stage. Yet this is the most important period for the miner. The long hours of daylight and the warm weather afford favorable opportunities for mining and sluicing, but the abundant supply of water needed for this purpose is often lacking.

THE FAIRBANKS DISTRICT.

DESCRIPTION OF AREA.

The area known as the Fairbanks district extends about 60 miles to the north of Fairbanks and is from 40 to 50 miles wide. The greater part of the region lies in the lower Tanana basin, but a portion to the northwest drains directly to the Yukon. Generally speaking, the district embraces three divisions—a low, broad, alluvial plain, a moderately high plateau, and a mountain mass.

The low, broad plain forms the bottom lands of the lower Tanana Valley, which in this section is divided into several parts by the Tanana and its sloughlike channels. The main slough starts near the mouth of Salcha River, about 30 miles above Fairbanks, where it diverts a portion of the Tanana waters. Its course is along the foothills of the plateau to the north, and it receives Chena River about 7 miles above Fairbanks. The plain is swampy and is well covered with timber along the banks of the streams. In the vicinity of Fairbanks it has a general elevation of about 500 feet above sea level.

The plateau is drained by streams tributary to Tanana River, which flow through rather broad, unsymmetrical valleys, most of which extend in a northeast-southwest direction. Their bottom lands range in elevation from 500 to over 2,000 feet above sea level, and the dividing ridges are in general 2,000 to 3,000 feet above the stream beds. That portion of the plateau which comes under discussion in this report is drained principally by Little Chena and Chatanika rivers. The upper region of these drainage basins is crosscut by a zigzag range, which separates the Yukon from the Tanana drainage.

The mountain mass north of this plateau forms what might be termed the apex of the divide between the Tanana and the Yukon drainage basins. Its highest points reach altitudes 4,000 to 5,000 feet above sea level, and its corrugated slopes are drained principally by tributaries to Yukon River.

All drainage areas tributary to the Tanana are similar in character. The streams have little slope except near their source and flow over wide gravelly beds in shifting and tortuous courses, keeping to one side of the valley. Most of the channels have rather steep banks that form approaches to broad, level bottom lands which extend 1,000 to 4,000 feet or more before they meet the abrupt slopes of the dividing ridges. The drainage basins are 4 to 15 miles wide and are cut up by small tributary streams that flow through deep and narrow ravines.

A large portion of the area is covered with a thick turf, known as tundra, which is wet, spongy, and mossy, and ranges in thickness from 6 inches to 2 feet. In some localities this is meadow-like, producing a rank growth of grass and a variety of beautiful wild flowers. Ground ice is found beneath this tundra in many places, particularly on the northern slopes, where the scanty soil supports little timber or other vegetation. The soil of the southern slopes is, for the most part, gravelly clay, underlain by a mica schist which affords suitable ground for ditch construction. When stripped of its mossy covering and exposed to the sun it thaws rapidly, so that the plow and scraper can be used to advantage.

Above altitudes of 2,000 to 2,200 feet practically the only vegetation is a scrubby, bushy growth which attains a height of 2 to 4 feet. In general the country below this altitude is timbered by spruce and birch, with scattered patches of tamarack and willow along the banks of the smaller streams. The timber increases in density and size toward the river bottoms, where the prevailing growth is spruce, much of which attains a diameter of 18 to 24 inches.

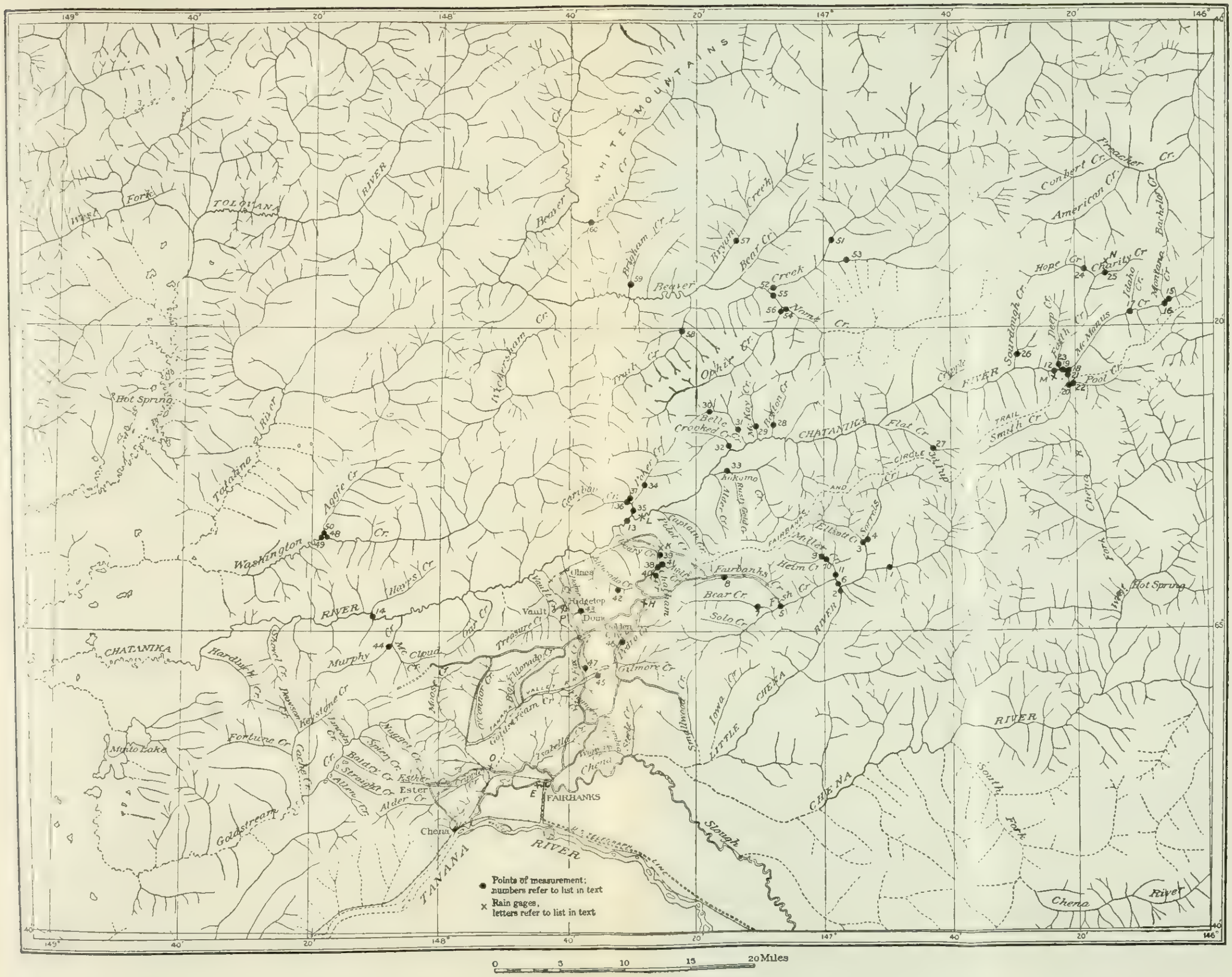
The Fairbanks mining district lies between Little Chena and Chatanika rivers. It embraces an area of about 500 square miles and extends 30 miles north of Fairbanks, which is situated on Chena Slough nearly 12 miles above its confluence with the Tanana. Most of the producing creeks rise in a high rocky ridge, of which Pedro Dome, with an elevation of about 2,500 feet, is the center. At least half of the mines are located at an elevation of over 800 feet, and 25 per cent are over 1,000 feet above sea level.

GAGING STATIONS.

The following list gives the points in the Fairbanks district at which gages were established or discharge measurements made in 1907 or 1908. The numbers refer to Plate II:

Gaging stations in Fairbanks district, 1907–1908.

1. Little Chena River above Elliott Creek.
2. Little Chena River below Fish Creek.
3. Elliott Creek above Sorrels Creek.
4. Sorrels Creek near mouth.
5. Fish Creek above Fairbanks Creek,
6. Fish Creek at mouth.



MAP SHOWING LOCATION OF GAGING STATIONS IN FAIRBANKS DISTRICT.

7. Bear Creek below Tecumseh Creek.
8. Fairbanks Creek.
9. Miller Creek above Heim Creek.
10. Miller Creek below Heim Creek.
11. Miller Creek near mouth.
12. Chatanika River near Faith Creek.
13. Chatanika River below Poker Creek.
14. Chatanika River below Murphy Creek.
15. McManus Creek above Montana Creek.
16. McManus Creek below Montana Creek.
17. McManus Creek below Idaho Creek.
18. McManus Creek above Smith Creek.
19. McManus Creek near mouth.
20. Smith Creek above Pool Creek.
21. Smith Creek near mouth.
22. Pool Creek near mouth.
23. Faith Creek near mouth.
24. Hope Creek near Zephyr Creek.
25. Charity Creek near mouth.
26. Sourdough Creek near mouth.
27. Flat Creek below 3d Pup.
28. Boston Creek at elevation 800 feet.
29. McKay Creek at elevation 800 feet.
30. Belle Creek at elevation 1,200 feet.
31. Belle Creek at elevation 800 feet.
32. Crooked Creek near mouth.
33. Kokomo Creek near mouth.
34. Poker Creek at elevation 800 feet.
35. Poker Creek near mouth.
36. Caribou Creek above Little Poker Creek.
37. Little Poker Creek near mouth.
38. Cleary Creek above Wolf Creek.
39. Cleary Creek near Cleary.
40. Chatham Creek at mouth.
41. Wolf Creek at mouth.
42. Eldorado Creek above trail.
43. Dome Creek near Dome.
44. Murphy Creek above McCloud Creek.
45. Goldstream Creek near claim 6 below.
46. Pedro Creek at claim 1 above.
47. Fox Creek at elevation 900 feet.
48. Washington Creek above Aggie Creek.
49. Washington Creek below Aggie Creek.
50. Aggie Creek at mouth.
51. Beaver Creek above East Branch.
52. Beaver Creek above Nome Creek.
53. East Branch of Beaver Creek near mouth.
54. Nome Creek above Ophir Creek.
55. Nome Creek near mouth.
56. Ophir Creek at mouth.
57. Bryan Creek at elevation 1,800 feet.
58. Trail Creek 4 miles above mouth.
59. Brigham Creek near mouth.
60. Fossil Creek near mouth.

LITTLE CHENA RIVER DRAINAGE BASIN.

GENERAL DESCRIPTION.

The southern slope of the divide between the Chatanika and Chena drainage basins, from the headwaters of Smith and Flat creeks to Pedro Dome, a distance of about 25 miles, is drained by Little Chena River and its tributaries, Elliott and Fish creeks. The drainage basin is irregular in shape and crossed by a network of small, ramifying streams with precipitous slopes in their upper courses. The upper portion of the main stream is also steep, having a fall of 100 to 150 feet to the mile, but this slope decreases rather abruptly to about 18 feet to the mile in the vicinity of Elliott and Fish creeks.

Above Fish Creek the Little Chena flows through a rather broad, unsymmetrical valley, but below that stream it takes the center of a deep, rather narrow channel for about 8 miles, to Anaconda Creek, an important tributary which enters from the left. Below this point the valley gradually widens again until the stream reaches the lowlands tributary to Chena River, with which it unites 6 or 8 miles above the confluence of Chena Slough. Through this slough the Chena discharges its waters into the Tanana near the town of Chena. The slough affords a passageway for the Tanana steamers from its mouth to Fairbanks, 12 miles above, except in times of low water, when the cargoes are transferred at Chena to the Tanana Valley Railroad.

In the low-water period the stream occupies a channel 30 to 75 feet wide, crossing from side to side of a broad, gravelly bed ranging in width from 100 to 300 feet. The channel is defined by steep, alluvial banks that form the approach to the heavily timbered bottom lands which prevail in the river valley above the confluence of Fish Creek. In the high-water stages the river completely fills its broad bed, overflowing the banks and seeking numerous smaller channels that surround heavily wooded islands.

The greater part of the drainage basin is well covered with timber, that in the uplands, on the slopes and smaller divides, consisting of spruce, birch, and poplar, suitable only for fuel and cabin purposes. In the lower valleys and creek bottom lands the prevailing growth is spruce, much of which is suitable for milling purposes.

The area is everywhere covered with the common moss, but here and there limestones, mica schist, and gravel outcrop on the slopes. In the creek valleys the mossy covering is usually underlain with frozen muck and glacial ice. The numerous swamp areas near the river banks and the heavy growth of timber make travel very difficult.

In 1907 gaging stations were established on Elliott Creek above Sorrels Creek, on Sorrels Creek above its mouth, on Fish Creek above Fairbanks Creek, and on the Little Chena about 2 miles above Elliott

Creek, and in 1908 additional stations were established on Little Chena below Fish Creek, on Fish Creek at its mouth, and on Miller Creek at mouth. Much credit is due Sherman White, the observer, for his faithful work in making approximately daily observations at each of these stations.

Drainage areas of Little Chena River basin.[a]

Stream and location.	Area.	Total area.
	Sq. miles.	*Sq. miles.*
Little Chena River above gaging station	79.0	79.0
Little Chena River from gaging station to mouth of Elliott Creek	3.6	82.6
Elliott Creek above gaging station	13.8	.....
Sorrels Creek above gaging station	21.0	.....
Elliott Creek from gaging station to mouth	3.8	.....
Total Elliott Creek	38.6	121.2
Little Chena River from mouth of Elliott to Fish Creek	6.0	127.2
Fish Creek above Bear Creek	23.6	.....
Bear Creek above mouth	12.0	.....
Fish Creek from Bear Creek to gaging station	3.6	.....
Fish Creek above gaging station	39.2	.....
Fairbanks Creek above mouth	20.5	.....
Fish Creek, Fairbanks Creek to Miller Creek	13.0	.....
Miller Creek above mouth	16.7	.....
Fish Creek from Miller Creek to mouth	.8	.....
Total Fish Creek	90.2	217.4
Little Chena from mouth of Fish Creek to Anaconda Creek	30.7	248.1
Anaconda Creek above mouth	43.3	291.4
Little Chena from Anaconda Creek to mouth	113.2	404.6

[a] From reconnaissance map Yukon-Tanana region, Fairbanks quadrangle.

LITTLE CHENA RIVER ABOVE ELLIOTT CREEK.

A gaging station was established on Little Chena River about 2 miles above Elliott Creek, July 22, 1907. At this point the channel is from 30 to 50 feet wide during low and medium stages. It has a gravelly bed and is fairly straight for about 100 feet. A stake graduated to feet and tenths was driven near the left side and daily readings were taken.

Discharge measurements of Little Chena River above Elliott Creek, 1907–1908.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1907.	*Feet.*	*Sec.-ft.*	1908.	*Feet.*	*Sec.-ft.*
July 22	0.60	44.2	May 29	1.65	249
July 24	.56	39.7	July 21	.46	32.3
August 4	1.10	113	July 31	.46	33.6
August 5	1.05	103			
August 20	.73	56.7			

Daily gage height and estimated discharge of Little Chena River above Elliott Creek, 1907–1908.

[Elevation, 800 feet; drainage area, 79 square miles.]

Day.	1907.						1908.							
	July.		August.		September.		May.		June.		July.		August.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			0.7	53	1.0	95				210		65		32
2			1.3	157	.9	80				197		58		32
3			1.1	113	.9	80			1.40	185		58		32
4			1.1	113	.8	66				160		58		29
5			1.1	113	.9	80				185		58		29
6			1.0	95	.95	88			1.55	223		58		29
7			1.05	104	.95	88				185		58	0.41	29
8			1.1	113	1.0	95				172		58	.50	35
9			1.2	134		95				160		46		35
10			1.1	113	1.0	95			1.25	148		46		32
11			1.0	95						160		46	.40	28
12			.9	80						172		46		30
13			1.0	95						172		46		30
14			.8	66						197		46	.45	32
15			.9	80					1.45	197		42		35
16			.8	66						160		42		38
17				66					1.20	136		38		42
18				60						148		38		46
19				60					1.10	113		35	.70	52
20			.7	53			2.20	405		113		35		58
21			.7	53				374		125	0.46	33		65
22	0.60	42	.7	53				374		94		33	.90	79
23		42	.7	53				346		94		33	.80	65
24	.60	42	.7	53				318		86		33		58
25	.60	42		73				290		86		33		52
26	.90	80	1.0	95				263		79		33	.65	46
27	.80	66	.9	80				236		79		33		
28	.70	53	.9	80				210		72		33		
29	.60	42		88			1.60	236		72		33		
30	.60	42	1.0	95				250		65		33		
31	.60	42	1.0	95				250			.45	33		
Mean		49.3		85.4		86.2		296		142		43.2		41.1
Mean per sq. mile		.625		1.08		1.09		3.75		1.80		.547		.520
Run-off, depth in inches		.23		1.24		.40		1.67		2.01		.63		.49

LITTLE CHENA RIVER BELOW FISH CREEK.

A gaging station was established on Little Chena River below the mouth of Fish Creek May 1, 1908. Measurements were made from a car and cable during high water and by wading in low water.

Discharge measurements of Little Chena River below Fish Creek, 1908.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
April 28	(a)	126	July 20	1.60	83
May 2	3.75	916	July 21	1.50	74.2
May 3	4.00	887	July 30	1.50	74.7
May 4	4.00	960	August 3	1.58	87.7
May 5	4.08	1,030	August 23	1.80	110

[a] Measurement made before gage was installed, river partly filled with ice.

Daily mean gage height and estimated discharge of Little Chena River below Fish Creek, 1908.

[Elevation, 700 feet; drainage area, 228 square miles.]

Day.	May.		June.		July.		August.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1	3.05	714	3.35	537	.....	161	1.48	68
2	3.70	746	2.95	367	.....	153	1.56	78
3	4.00	960	2.65	274	.....	145	1.58	80
4	4.00	960	2.48	231	.....	145	1.54	74
5	4.05	998	3.48	608	.....	137	1.49	68
6	4.15	1,075	3.55	651	.....	129	1.44	62
7	3.90	885	3.00	384	.....	122	1.45	64
8	3.71	753	2.80	318	.....	115	1.50	70
9	3.68	732	2.48	230	.....	108	1.50	70
10	3.70	746	2.31	192	.....	108	1.49	68
11	.....	732	2.40	212	.....	108	1.45	64
12	3.65	714	2.60	260	.....	101	1.40	59
13	3.68	732	2.55	248	.....	95	1.40	59
14	3.70	746	2.68	282	.....	88	1.46	65
15	3.98	940	2.98	378	.....	82	1.49	68
16	4.85	1,668	2.58	256	.....	76	1.52	72
17	4.68	1,510	2.50	235	.....	70	1.62	84
18	4.38	1,265	2.70	288	.....	70	1.60	82
19	4.38	1,265	2.45	224	.....	82	1.65	88
20	4.44	1,320	2.40	212	1.60	82	1.70	95
21	4.38	1,265	.....	235	1.50	70	1.82	111
22	3.88	870	.....	303	.....	70	1.90	122
23	3.50	620	.....	260	.....	70	1.75	101
24	3.52	632	.....	212	.....	70	1.72	98
25	3.20	465	.....	212	.....	70	1.70	95
26	2.82	324	.....	201	.....	70	1.64	85
27	2.62	265	.....	190	.....	70	1.65	88
28	3.25	489	.....	180	.....	70	.....	.....
29	3.15	443	.....	170	1.50	70	.....	.....
30	3.15	443	.....	161	1.50	70	.....	.....
31	3.30	512	.....	.....	1.45	64	.....	.....
Mean	.....	832	.....	284	.....	94.9	.....	79.2
Mean per square mile	.....	3.65	.....	1.25	.....	.416	.....	.347
Run-off, depth in inches	.....	4.21	.....	1.40	.....	.48	.....	.35

ELLIOTT CREEK ABOVE SORRELS CREEK.

Elliott Creek takes the drainage from the southern slope of Twin Butte Hills, in the Chatanika divide, and flows southward, discharging its waters and those of Sorrels Creek, its tributary, into the Little Chena about 4 miles above Fish Creek.

The drainage area is steep in its upper reaches and well timbered in the creek bottom. The stream flows in a narrow channel, rather deeply cut, and the banks are lined with willow and small spruce.

A gaging station was established about half a mile above the mouth of Sorrels Creek July 22, 1907, and regular readings were taken.

Discharge measurements of Elliott Creek above Sorrels Creek, 1907–1908.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1907.	*Feet.*	*Sec.-ft.*	1908.	*Feet.*	*Sec.-ft.*
July 23	1.6	5.1	May 29	2.15	32.5
August 5	1.85	13.8	July 21	1.35	4.4
August 20	1.615	7.1	July 31	1.35	4.5

Daily gage height and estimated discharge of Elliott Creek above Sorrels Creek, 1907–1908.

[Elevation, 800 feet; drainage area, 13.8 square miles.]

Day.	1907.						1908.							
	July.		August.		September.		May.		June.		July.		August.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1	.....	.....	1.7	9.0	1.8	12.3	.....	.....	.....	26.0	.....	7.5	.....	4.5
2	.....	.....	2.1	23	1.8	12.3	.....	.....	.....	17	.....	7.5	.....	4.5
3	.....	.....	2.1	23	1.7	9.0	.....	.....	1.85	13	.....	7.5	.....	4.5
4	.....	.....	.....	17.2	1.7	9.0	.....	.....	.....	13	.....	6.6	.....	4.4
5	.....	.....	1.8	12.3	1.7	9.0	.....	.....	.....	11	.....	6.6	.....	4.4
6	.....	.....	1.8	12.3	.....	9.0	.....	.....	1.80	11	.....	6.0	.....	4.4
7	.....	.....	.....	12.3	.....	9.0	.....	.....	.....	15	.....	6.0	1.30	4.4
8	.....	.....	1.8	12.3	1.7	9.0	.....	.....	.....	17	.....	6.0	1.33	4.5
9	.....	.....	1.9	15.6	.....	10.0	.....	.....	.....	22	.....	5.4	.....	4.4
10	.....	.....	1.8	12.3	.....	12.0	.....	.....	2.15	32	.....	5.4	.....	4.4
11	.....	.....	1.8	12.3	.....	.....	.....	.....	.....	32	.....	5.0	1.29	4.4
12	.....	.....	1.7	9.0	.....	.....	.....	.....	.....	26	.....	5.0	.....	4.4
13	.....	.....	1.8	12.3	.....	.....	.....	.....	.....	26	.....	5.0	.....	4.4
14	.....	.....	1.8	12.3	.....	.....	.....	.....	.....	22	.....	5.0	1.34	4.5
15	.....	.....	1.7	9.0	.....	.....	.....	.....	2.00	20	.....	5.0	.....	4.5
16	.....	.....	1.7	9.0	.....	.....	.....	.....	.....	15	.....	4.6	.....	4.5
17	.....	.....	.....	9.0	.....	.....	.....	.....	1.75	9.5	.....	4.6	.....	4.5
18	.....	.....	.....	7.4	.....	.....	.....	.....	.....	9.3	.....	4.6	.....	4.5
19	.....	.....	1.65	7.4	.....	.....	.....	.....	1.73	9.1	.....	4.6	1.35	4.5
20	.....	.....	1.6	5.8	.....	.....	3.30	216	.....	8.9	.....	4.6	.....	4.5
21	.....	.....	1.6	5.8	.....	.....	.....	184	.....	9.5	.....	4.5	.....	4.6
22	1.6	5.8	1.6	5.8	.....	.....	.....	120	.....	9.5	.....	4.5	1.40	4.6
23	1.6	5.8	1.6	5.8	.....	.....	.....	56	.....	9.5	.....	4.5	.....	4.6
24	1.6	5.8	1.6	5.8	.....	.....	.....	40	.....	9.5	.....	4.5	.....	4.6
25	1.6	5.8	.....	7.4	.....	.....	.....	22	.....	9.5	.....	4.5	.....	4.5
26	1.7	9.0	1.7	9.0	.....	.....	.....	11	.....	8.6	.....	4.5	1.34	4.5
27	1.7	9.0	1.7	9.0	.....	.....	.....	15	.....	8.6	.....	4.5	.....	.....
28	1.6	5.8	1.8	12.3	.....	.....	.....	22	.....	8.6	.....	4.5	.....	.....
29	1.6	5.8	.....	12.3	.....	.....	2.15	32	.....	8.6	.....	4.5	.....	.....
30	.....	4.1	.....	12.3	.....	.....	.....	48	.....	8.6	.....	4.5	.....	.....
31	1.5	2.5	1.8	12.3	.....	.....	.....	48	.....	.....	.....	4.5	.....	.....
Mean	.....	5.94	.....	11.0	.....	10.0	.....	67.8	.....	14.8	.....	5.22	.....	4.48
Mean per square mile.	.....	.430	.....	.797	.....	.724	.....	4.91	.....	1.07	.....	.378	.....	.324
Run-off, depth in inches	.....	.16	.....	.92	.....	.27	.....	2.19	.....	1.19	.....	.44	.....	.31

SORRELS CREEK.

Sorrels Creek rises in the Chatanika divide west of Flat Creek, and flows westward along this divide for about 5 miles, then, by an abrupt bend to the left, it takes a southerly course for about 6 miles to Elliott Creek, uniting with the latter about 3 miles above its mouth. The stream flows in a narrow irregular channel, rather deeply cut in the mucklike bottom lands, and is well hidden from view by the masses of spruce and willow along its banks.

A gaging station was established on this stream about one-half mile above its mouth July 23, 1907, and regular readings were taken.

Discharge measurements of Sorrels Creek near mouth, 1907–1908.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1907.	*Feet.*	*Sec.-ft.*	1908.	*Feet.*	*Sec.-ft.*
July 23	1.00	10.3	May 29	1.75	54.3
August 5	1.40	28.2	July 21	1.09	11.3
August 20	1.02	12.0	July 31	1.03	10.5

Daily gage height and estimated discharge of Sorrels Creek near mouth, 1907–1908.

[Elevation, 800 feet; drainage area, 21 square miles.]

Day.	1907.						1908.							
	July.		August.		September.		May.		June.		July.		August.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1	.....	.....	1.1	14.7	1.2	19.0	.....	.....	.....	66	.....	38	.....	11
2	.....	.....	1.4	27.8	1.2	19.0	.....	.....	.....	50	.....	36	.....	11
3	.....	.....	1.4	27.8	1.1	14.7	.....	.....	1.55	36	.....	35	.....	10
4	.....	.....	1.5	32.1	1.1	14.7	.....	.....	.....	34	.....	34	.....	10
5	.....	.....	1.35	25.6	1.1	14.7	.....	.....	.....	28	.....	32	.....	10
6	.....	.....	1.3	23.4	.....	14.7	.....	.....	1.45	30	.....	30	.....	10
7	.....	.....	.....	23.4	.....	14.7	.....	.....	.....	30	.....	29	1.00	10
8	.....	.....	1.3	23.4	1.1	14.7	.....	.....	.....	29	.....	28	1.02	10
9	.....	.....	1.4	27.8	.....	14.7	.....	.....	.....	28	.....	27	.....	10
10	.....	.....	1.3	23.4	.....	19.0	.....	.....	1.40	27	.....	25	.....	10
11	.....	.....	1.3	23.4	.....	.....	.....	.....	.....	29	.....	23	.99	10
12	.....	.....	1.2	19.0	.....	.....	.....	.....	.....	31	.....	22	.....	10
13	.....	.....	1.2	19.0	.....	.....	.....	.....	.....	39	.....	21	.....	10
14	.....	.....	1.2	19.0	.....	.....	.....	.....	.....	37	.....	20	1.01	10
15	.....	.....	1.1	14.7	.....	.....	.....	.....	1.60	40	.....	19	.....	11
16	.....	.....	1.1	14.7	.....	.....	.....	.....	.....	42	.....	17	.....	13
17	.....	.....	.....	14.7	.....	.....	.....	.....	1.65	45	.....	16	.....	15
18	.....	.....	.....	12.5	.....	.....	.....	.....	.....	50	.....	15	.....	15
19	.....	.....	.....	10.3	.....	.....	.....	.....	1.65	45	.....	14	1.15	15
20	.....	.....	1.0	10.3	.....	.....	2.30	131	.....	45	.....	13	.....	16
21	.....	.....	1.0	10.3	.....	.....	.....	113	.....	60	1.08	12	.....	17
22	1.0	10.3	1.0	10.3	.....	.....	.....	98	.....	72	.....	12	1.22	18
23	1.0	10.3	1.0	10.3	.....	.....	.....	84	.....	60	.....	11	.....	17
24	1.0	10.3	1.0	10.3	.....	.....	.....	72	.....	57	.....	11	.....	17
25	1.0	10.3	.....	12.5	.....	.....	.....	60	.....	54	.....	11	.....	15
26	1.1	14.7	1.1	14.7	.....	.....	.....	50	.....	50	.....	11	1.10	13
27	1.1	14.7	1.1	14.7	.....	.....	.....	36	.....	48	.....	11	.....	.....
28	1.0	10.3	1.2	19.0	.....	.....	.....	45	.....	45	.....	11	.....	.....
29	1.0	10.3	.....	19.0	.....	.....	1.75	55	.....	42	.....	11	.....	.....
30	.....	8.2	.....	19.0	.....	.....	.....	66	.....	40	.....	11	.....	.....
31	.9	6.0	1.2	19.0	.....	.....	.....	66	.....	.....	1.03	11	.....	.....
Mean		10.5	.....	18.2	.....	16.0	.....	73.0	.....	42.8	.....	19.9	.....	12.5
Mean per square mile.		.500	.....	.867	.....	.762	.....	3.48	.....	2.04	.....	.948	.....	.595
Run-off, depth in inches		.19	.....	1.00	.....	.28	.....	1.55	.....	2.28	.....	1.09	.....	.58

FISH CREEK ABOVE FAIRBANKS CREEK.

Fish Creek rises in the high ridge at the head of Goldstream Creek and flows northwestward through an irregularly formed valley. About 14 miles below its source it makes an abrupt bend to the right, rounding the point of a rather steep divide that separates its drainage from that of the Little Chena, into which it discharges about 2 miles below this bend. Its course is tortuous and closely follows the right side of the valley, the left side of which is a broad, marshy bot-

tom land. Its principal tributaries are Solo, Bear, Fairbanks, and Miller creeks, all from the left. The upper slopes of these streams are rather steep, but they become rapidly less as Fish Creek Valley is approached.

A gaging station was established a short distance above Fairbanks Creek July 22, 1907, and regular readings were taken.

Discharge measurements of Fish Creek above Fairbanks Creek, 1907–1908.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1907.	*Feet.*	*Sec.-ft.*	1908.	*Feet.*	*Sec.-ft.*
July 21	1.00	23.7	May 31	2.40	107.0
July 25	1.00	24.3	July 18	.85	16.0
August 3	1.55	47.8	July 19	.85	16.8
August 4	1.35	37.6	July 22	.75	12.8
August 19	1.00	20.8	July 29	.75	15.4
			August 5	.75	15.0

Daily gage height and estimated discharge of Fish Creek above Fairbanks Creek, 1907–1908.

[Elevation, 925 feet; drainage area, 39 square miles.]

Day.	1907.						1908.							
	July.		August.		September.		May.		June.		July.		August.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			3.2	155	1.0	24			2.35	102		33		13.5
2			2.4	100	1.0	24				86		31		13.5
3			1.4	39	1.0	24				79		31		13.5
4			1.3	35	1.0	24				71		29		13.5
5				37	1.1	27			1.95	71		29	0.75	13.5
6			1.4	39		27			2.70	137		29		13.5
7			1.55	47		27				98		26		13.5
8			1.3	35	1.1	27				68		26		13.5
9			1.6	50	1.1	27			1.40	38		24		13.5
10			1.6	50	1.3	35				43		24	.75	13.5
11				39						55		22		13.5
12			1.2	31					1.80	61		22		12.0
13			1.1	27						55		22	.70	12.0
14			1.1	27	2.6	[a]115				52		20		13.5
15			1.1	27					1.50	43		18		15.0
16			1.0	24					1.50	43		18		15.0
17			1.0	24						41		16.5	.82	15.6
18				24						41	0.85	16.5		16.2
19			1.0	24						38	.85	16.5		16.5
20				24					1.40	38		15.0		16.8
21			1.0	24						43		12.0	.89	17.7
22	1.0	24	1.0	24			3.60	227		55	.75	13.5		17.4
23		24		24				197		52		13.5		17.1
24		24	1.0	24				167		49		13.5		16.8
25	1.0	24	1.1	27				127		46		13.5		16.5
26	1.1	27	1.1	27				90		43		13.5		16.1
27	1.0	24	1.0	24				94		41		13.5	.82	15.6
28	.9	21	1.0	24				98		38		13.5		
29	.9	21		27				102		38	.75	13.5		
30	.8	18	1.2	31				107		36		13.5		
31	.8	18	1.1	27			2.40	107				13.5		
Mean		22.5		36.8		26.6		132		56.7		19.9		14.8
Mean per square mile.		.577		.944		.682		3.38		1.45		.510		.380
Run-off, depth in inches		.21		1.09		.25		1.26		1.61		.59		.38

[a] Not included in mean.

FISH CREEK AT MOUTH.

A gaging station was established at the mouth of Fish Creek May 1, 1908. Measurements were made from a car and cable during high water and by wading in low water.

Discharge measurements of Fish Creek at mouth, 1908.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
May 5	4.22	618	May 28	2.30	148
May 6	3.98	530	May 30	2.75	208
Do	4.20	646	July 20	.90	26.0
May 7	3.90	558	July 21	.88	26.1
Do	4.02	571	July 30	.82	24.6
May 8	3.64	385	August 2	1.00	29.2
May 9	3.70	525	August 23	1.10	32.4

Daily mean gage height and estimated discharge of Fish Creek at mouth, 1908.

[Elevation, 700 feet; drainage area, 90.2 square miles.]

Day.	May.		June.		July.		August.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1	3.98	564	2.60	206	.....	65	0.82	23
2	4.00	570	2.28	147	.....	61	.99	28
3	4.25	650	1.98	105	.....	57	.98	28
4	4.35	682	1.80	83	.....	53	.92	25
5	4.28	660	2.25	142	.....	49	.87	24
6	4.05	586	3.12	327	.....	45	.82	22
7	3.95	554	2.42	170	.....	42	.85	24
8	3.65	464	2.22	138	.....	38	.89	25
9	3.65	464	1.90	95	.....	35	.90	25
10	3.65	464	1.65	69	.....	33	.88	25
11	.....	445	1.75	78	.....	31	.84	24
12	3.50	422	2.28	146	.....	30	.80	22
13	3.45	409	2.15	128	.....	28	.80	22
14	3.50	422	2.18	132	.....	27	.87	24
15	3.48	417	2.58	202	.....	25	.88	25
16	4.40	396	2.10	121	.....	24	.90	25
17	4.35	383	2.10	121	.....	22	.99	28
18	3.90	538	2.62	210	.....	22	.95	27
19	3.78	500	2.05	114	.....	24	.94	27
20	3.75	493	1.90	95	.....	25	.94	27
21	3.52	429	.....	114	.....	25	1.08	31
22	3.15	334	.....	142	.....	25	1.10	31
23	2.78	246	.....	114	.....	25	1.00	28
24	2.55	196	.....	95	.....	24	.98	28
25	2.50	186	.....	89	.....	24	.96	27
26	2.25	142	.....	83	.....	24	.95	27
27	1.98	105	.....	78	.....	24	1.00	28
28	2.25	142	.....	73	.....	24	.....	.....
29	2.40	166	.....	73	0.85	24	.....	.....
30	2.80	250	.....	69	.82	23	.....	.....
31	2.80	250	.....	.....	.79	22	.....	.....
Mean	.....	404	.....	125	.....	32.2	.....	25.9
Mean per square mile	.....	4.48	.....	1.39	.....	.356	.....	.287
Run-off, depth in inches	.....	5.16	.....	1.55	.....	.41	.....	.28

BEAR CREEK.

Bear Creek rises in the high divide at the head of Goldstream Creek, flows eastward through a deep, narrow valley, and unites with Fish Creek about one-half mile above the gaging station. The following measurements were made below Tecumseh Creek: July 20, 1907, 8.4 second-feet; August 22, 1907, 7 second-feet; July 19, 1908, 5.4 second-feet; drainage area, 12 square miles; discharge per square mile, 0.70, 0.584, and 0.450 second-feet, respectively.

FAIRBANKS CREEK.

Fairbanks Creek rises on the eastern side of Pedro Dome, opposite the headwaters of Cleary Creek, and flows eastward about 10 miles to Fish Creek. It is separated from Bear Creek on the right by a steep, high ridge, rising 800 to 1,000 feet above the stream bed. The valley to the left is more gradual in slope, and is drained by several small tributaries—Moose, Crane, Alder, Walnut, and Deep creeks. The stream flows close to the dividing ridge on the east until it approaches the broad lowland near Fish Creek. Its lower course lies through a narrow, deep-cut channel, thickly lined with willow and spruce. The stream has rather steep slopes in its upper course. Below Moose Creek the average fall is about 75 feet to the mile.

Discovery claim is located near Alder Creek, and mining operations are carried on from claim 9 above to claim 13 below. The pay streak follows the stream channel closely down to claim 9 below, where it swings to the left limit. Above claim 2 below, most of the work is by the open-cut method. Below this point it is underground by drifting. The following measurements were made in 1907, but owing to the unfavorable conditions they are approximate only.

Discharge measurements of Fairbanks Creek, 1907.

Date.	Elevation.	Discharge.	Date.	Elevation.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
June 24	1,300	1.4	July 5	1,375	.72
Do	1,250	2.2	July 20	1,400	1.3

MILLER CREEK.

Miller Creek rises in the southeastern slope of Coffee Dome and flows southward, joining Fish Creek about 1 mile above its confluence with Little Chena River. It is about 6 miles long and flows through a narrow valley, draining an area of 16.7 square miles. A regular station was established at the mouth of the creek May 13, 1908, and several miscellaneous measurements were made in 1907 and 1908.

Discharge measurements of Miller Creek at mouth, 1908.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
May 28	1.20	27.9	July 21	.60	4.9
Do	1.20	23.2	July 30	.58	4.86
May 30	1.32	29.4	August 3	.62	5.78
July 20	.60	4.2			

Daily mean gage height and estimated discharge of Miller Creek at mouth, 1908.

[Elevation, 750 feet; drainage area, 16.7 square miles.]

Day.	May.		June.		July.		August.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			1.40	39.2		11.1	0.58	4.6
2			1.10	19.6		10.8	.62	5.3
3			.98	14.8		10.6	.62	5.3
4			.90	12		10.3	.60	4.9
5			1.14	22		10.0	.58	4.6
6			1.60	55.2		9.7	.58	4.6
7			1.10	19.6		9.4	.58	4.6
8			1.02	16.1		9.2	.60	4.9
9			.88	11.4		8.9	.60	4.9
10			.85	10.6		8.6	.58	4.6
11			.90	12.0		8.4	.56	4.3
12			1.18	23.6		8.2	.54	4
13	2.05	91.2	1.28	29.8		8.0	.54	4
14	2.08	94.2	1.32	32.8		7.8	.60	4.9
15	2.18	101	1.24	26.2		7.6	.60	4.9
16	2.45	122	1.02	16.1		7.4	.62	5.3
17	2.42	120	.95	13.8		7.2	.60	4.9
18	2.20	103	1.10	19.6		7.0	.60	4.9
19	2.18	101	.89	11.7		6.8	.60	4.9
20	2.15	99.2	.88	11.4		6.6	.61	5.1
21	1.90	79.2		13.8		6.4	.67	6.4
22	1.60	55.2		15.4		6.2	.67	6.4
23	1.22	26		13.8		5.9	.65	5.9
24	1.22	26		13.4		5.7	.62	5.3
25	1.15	22		13		5.5	.61	5.1
26	.95	13.8		12.6		5.3	.60	4.9
27	.98	14.8		12.3		5.1	.61	5.1
28	1.18	23.6		12.0		4.9		
29	1.28	29.8		11.7	0.60	4.9		
30	1.35	35.2		11.4	.58	4.6		
31	1.35	35.2			.55	4.3		
Mean		62.7		18.2		7.50		4.98
Mean per square mile		3.77		1.08		.449		.298
Run-off, depth in inches		2.65		1.20		.52		.30

Miscellaneous measurements of Miller Creek, 1907–1908.

Date.	Point of measurement.	Elevation.	Drainage area.	Discharge.	Discharge per square mile.
1907.		*Feet.*	*Sq. miles.*	*Sec.-ft.*	*Sec.-ft.*
July 6	Near mouth	750	15	7.0	0.466
July 24	do	750	15	7.6	.506
August 20	do	750	15	8.0	.533
August 6	Below mouth of Heim Creek	790	10	8.0	.800
August 7	do	790	10	8.0	.800
Do	Above mouth of Heim Creek	800	6	4.9	.816
1908.					
July 21	do	800	6	2.5	.416
August 1	do	800	6	2.2	.366
July 21	Below mouth of Heim Creek	790	10	3.1	.310
August 1	do	790	10	2.4	.240

CHATANIKA RIVER DRAINAGE BASIN.

GENERAL DESCRIPTION.

Chatanika River is formed by the junction of Faith and McManus creeks, which drain the high ridge constituting the divide between the lower Tanana and Yukon basins. The river flows southwestward, in a winding course, through a long and rather narrow valley, and unites with the Tolovana from the east about 30 miles above the confluence of that stream with the Tanana. Its course lies mostly to the western side of the valley, which is from one-half mile to 7 miles wide and about 80 miles long. The drainage area of the river above its mouth is approximately 1,300 square miles.

From the junction of Faith and McManus creeks the stream has a shifting, gravelly bottom. In low and medium stages it flows in a series of pools and rapids in a channel 75 to 200 feet wide; during the high-water period it may spread through several channels covering a width of 100 to 400 feet. This high-water channel is usually well defined by steep, alluvial banks ranging from 8 to 10 feet in height.

Below Poker Creek, a tributary from the right about 40 miles downstream from the junction, the valley widens and the bottom lands become marshy and swampy. From the left, the Chatanika receives drainage from Cleary, Eldorado, Dome, and Vault creeks, and other less important streams from the mining district proper. Below these tributaries the valley narrows to a gorgelike channel, which it follows for about 10 miles, after which the dividing ridges disappear and the stream meanders through the low swampy grounds to the north of Tanana River. About 10 miles from its mouth Goldstream Creek, its largest tributary, joins it from the left.

The average elevation of the divides in the upper drainage area of the Chatanika is between 3,000 and 4,000 feet above sea level, and the altitude of the ridges bounding the valley on the east and west is

about 2,000 feet. Below an altitude of 1,800 to 2,000 feet the slopes are heavily timbered.

The tributary streams from the right are short and precipitous, flowing through V-shaped valleys; those from the left have less precipitous courses and broader valleys and gradually lose themselves in the rather broad expanse of swamplike bottom lands.

The altitude and drainage area of the upper Chatanika has attracted the attention of "outside" capital for some time. The general topography has seemed suitable for a possible water supply by ditch line to the mining district proper, and the favorable slope of portions of Faith and McManus creeks has made them attractive to the promotor for hydraulicking.

Several gaging stations were established in this drainage basin during 1907. In June A. D. Gassaway, general manager of the Chatanika Ditch Company, began the first records of actual stream flow in this section by establishing gaging weirs at the mouth of Faith and McManus creeks.

Through the courtesy of this company the records are published in this report.

CHATANIKA RIVER NEAR FAITH CREEK.

A gaging station was established July 10, 1907, on the Chatanika, about 2,000 feet below the confluence of Faith and McManus creeks, and readings were taken twice each day by M. T. Kerrick, an employee of the Chatanika Ditch Company. The 1908 readings were made by Herman Salchow, proprietor of Faith Creek Road House.

Discharge measurements of Chatanika River near Faith Creek, 1907–1908.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
1907.		*Feet.*	*Sec.-ft.*	1908.		*Feet.*	*Sec.-ft.*
July 16	C. C. Covert	1.58	51.9	May 13	C. W. McConaughy	[a]3.48	396
July 26	E. B. Brigham	1.80	80.5	May 14	do	[a]3.37	300
August 3	do	1.89	96.5	Do	do	[a]3.54	367
August 7	do	2.26	188	May 21	do	4.15	1,340
				June 26	do	1.95	130
1908.				July 12	C. C. Covert	2.05	144
May 11	C. W. McConaughy	[a]3.90	311	July 13	C. E. Ellsworth	2.15	178
May 13	do	[a]3.40	297	Do	do	2.03	119
Do	do	[a]3.40	334	August 31	C. C. Covert	2.05	142

[a] Backwater from ice jam below station.

Daily gage height and estimated discharge of Chatanika River near Faith Creek, 1907–1908.

[Elevation, 1,350 feet; drainage area, 132 square miles.]

Day.	1907.[a]						1908.							
	July.		August.		September.		May.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			1.80	82	2.08	145						140	2.4	270
2			2.02	131	2.03	133						140	2.5	320
3			1.86	96	2.00	126						125	2.9	530
4			1.93	109	2.01	128						125	2.7	420
5			1.95	114	2.06	140						102		370
6			1.95	114	2.01	128						102	2.5	320
7			2.25	205	1.98	121						100	2.4	270
8			2.12	157	2.02	131						100	2.3	225
9			2.05	138	1.99	124						102	2.3	225
10			2.02	131	1.97	119						102	2.3	225
11			1.92	107	2.34	243	4.17	430				100	2.2	185
12			1.85	95	5.00	1,990	3.76	470				95	2.1	150
13			1.85	95	3.20	710	3.45	340	2.1	150		95	2.1	150
14			1.80	82	2.86	503	3.45	340	2.1	150		102	2.1	150
15			1.80	82	2.77	453	3.47	350	1.9	102		102	2.1	150
16			1.80	82	3.24	734	3.54	380	2.1	150		114	2.2	185
17	1.65	60	1.80	82	3.05	620	3.51	370	1.9	102	2.0	126	2.2	185
18	1.86	96	1.78	78	2.78	463	3.42	320	2.0	126	2.1	150	2.1	150
19	1.80	82	1.75	72	2.63	385	3.56	390	1.9	102	2.1	150	2.1	150
20	1.75	72	1.75	72	2.56	350	4.11	1,300	1.9	102	2.2	185	2.1	150
21	1.70	66	1.75	72	2.50	320	4.15	1,340	1.8	82	2.4	270	2.0	126
22	1.62	57	1.98	121	2.43	285			1.8	82	2.4	270	2.0	126
23	1.60	55	1.92	107	2.35	248			1.9	102	2.3	225	2.0	126
24	1.64	59	2.04	136	2.31	230			2.0	126	2.2	185	2.1	150
25	1.75	72	2.22	193	2.29	221			2.0	126	2.0	126	2.3	225
26	1.85	95	2.25	205	2.29	221			2.0	126	2.0	126	2.2	185
27	1.75	72	2.15	168	2.30	225				150	2.0	126	2.1	150
28	1.67	62	2.13	161	2.34	243				175	2.1	150	2.1	150
29	1.65	60	2.25	205	2.42	280				200	2.1	150	2.0	126
30	1.60	55	2.25	205	2.36	252				180	2.1	150	(b)	102
31	1.60	55		171						150	2.0	126		
Mean		67.8		125		342		598		131		137		208
Mean per square mile		.514		.947		2.59		4.53		.992		1.04		1.58
Run-off, depth in inches		.28		1.09		2.89		1.85		.70		1.20		1.76

[a] Revised from 1908 curve. [b] The river was frozen after September 30, 1908.

CHATANIKA RIVER BELOW POKER CREEK.

A gaging station was established on Chatanika River below Poker Creek June 20, 1907. A post gage driven firmly in the ground near the log chute of the Cleary Creek Lumber Company's mill was read twice each day by J. Fitzsimmons.

Discharge measurements of Chatanika River below Poker Creek, 1907–1908.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1907.	*Feet.*	*Sec.-ft.*	1908.	*Feet.*	*Sec.-ft.*
June 22	1.08	246	August 8	0.95	207
July 4	.83	178	August 14	.90	192
August 9	1.98	669	August 22	1.85	420

Daily mean gage height and estimated discharge of Chatanika River below Poker Creek, 1907.

[Elevation 700 feet; drainage area, 456 square miles. Discharges over 1,000 second-feet are approximate.]

Day.	June.		July.		August.		September.		October.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			0.9	192	2.1	752	1.45	384	2.25	860
2			.9	192	2.6	1,160	1.4	363	2.0	680
3			.9	192	2.0	680	1.3	321	1.85	590
4			.8	167	1.75	530	1.3	321	1.75	530
5			.8	167	1.75	530	1.25	300	1.70	505
6			.8	167	1.65	480	1.3	321	1.65	480
7			.8	167	1.5	405	1.3	321	1.6	455
8			.95	204	1.75	530	1.3	321	1.45	384
9			.85	180	1.9	620	1.45	384	1.25	300
10			.8	167	1.85	590	1.3	321	1.05	232
11			.9	192	1.6	455	1.35	342	1.45	384
12			.9	192	1.5	405	3.6	2,160	1.85	590
13			.95	204	1.35	342	4.45	3,160	1.8	560
14			.9	192	1.4	363	3.25	1,780	1.75	530
15			1.0	216	1.25	300	2.85	1,390	(a)	
16			1.05	232	1.2	283	4.0	2,620		
17			1.1	250	1.1	250	4.3	2,980		
18			1.1	250	1.1	250	2.35	942		
19			1.2	283	1.0	216	2.5	1,060		
20	1.1	250	1.15	266	1.1	250	2.3	901		
21	1.1	250	1.1	250	1.1	250	2.35	942		
22	1.1	250	1.1	250	1.0	216	2.3	901		
23	1.1	250	.95	204	1.15	266	2.25	860		
24	1.05	232	.9	192	1.2	283	2.15	788		
25	1.0	216	.9	192	1.35	342	2.0	680		
26	.9	192	1.05	232	1.55	430	2.0	680		
27	.9	192	1.1	250	1.3	321	2.0	680		
28	1.0	216	1.1	250	1.4	363	2.0	680		
29	1.1	250	1.1	250	1.55	430	2.15	788		
30	1.0	216	1.0	216	1.7	505	2.35	942		
31			.9	192	1.6	455				
Mean		228		211		428		954		506
Mean per square mile		.500		.463		.939		2.09		1.11
Run-off, depth in inches		.20		.53		1.08		2.33		.68

(a) The river was frozen over after October 14.

Daily mean gage height and estimated discharge of Chatanika River below Poker Creek, 1908.

[Elevation, 700 feet; drainage area, 456 square miles. Discharges over 1,000 second-feet are approximate.]

Day.	May.		June.		July.		August.		September.		October.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			3.7	2,280	1.4	363	1.15	266	1.3	321	1.15	266
2			3.3	1,830	1.35	342	1.15	266	1.45	384	1.25	300
3			3.05	1,580	1.15	266	1.15	266	2.1	752	1.35	342
4			2.6	1,160	1.85	590	1.05	232	2.6	1,160	1.2	283
5			2.9	1,430	1.55	430	1.05	232	2.35	942	1.15	266
6			3.65	2,220	1.45	384	.95	204	2.1	752	1.05	232
7			2.6	1,160	1.45	384	.95	204	1.95	650	1.05	232
8			2.6	1,160	1.5	405	.95	204	1.8	560	1.15	266
9			2.2	824	2.35	942	1.0	216	1.75	530	1.0	216
10			1.95	650	1.8	560	1.0	216	1.6	455	.95	204
11			2.15	788	1.45	384	.95	204	1.55	430	1.05	232
12			2.35	942	1.35	342	.95	204	1.5	405	1.05	232
13			2.95	1,480	1.35	342	.9	192	1.45	384	1.0	216
14			2.9	1,430	1.25	300	.9	192	1.35	342	.95	204
15			3.25	1,780	1.2	283	.95	204	1.25	300	.85	179
16	4.35	3,040	2.5	1,060	1.2	283	1.05	232	1.35	342	.85	179
17	4.55	3,280	2.65	1,200	1.35	342	1.2	283	1.4	363	1.0	216
18	4.5	3,220	2.45	1,020	1.25	300	1.35	342	1.5	405	1.05	232
19	4.6	3,340	2.2	824	1.2	283	1.4	363	1.8	560	1.05	232
20	4.6	3,340	2.05	716	1.1	250	1.5	405	1.7	505	1.0	216
21	5.25	4,120	1.95	650	.95	204	1.6	455	1.5	405	.85	179
22	4.75	3,520	1.8	560	.95	204	1.6	455	1.45	384	(a)	.....
23	3.55	2,110	1.6	455	.95	204	1.55	430	1.45	384	.....	.....
24	4.2	2,860	1.5	405	1.0	216	1.4	363	1.3	321	.....	.....
25	4.3	2,980	1.35	342	.95	204	1.35	342	1.25	300	.....	.....
26	3.65	2,220	1.3	321	.95	204	1.3	321	1.25	300	.....	.....
27	3.45	2,000	1.2	283	.95	204	1.25	300	1.3	321	.....	.....
28	3.2	1,730	1.3	321	1.0	216	1.25	300	1.25	300	.....	.....
29	3.45	2,000	1.4	363	1.2	283	1.25	300	1.15	266	.....	.....
30	3.55	2,110	1.2	283	1.25	300	1.25	300	1.25	300	.....	.....
31	3.35	1,890	.....	.....	1.2	283	1.25	300	.....	.....	.....	.....
Mean	.....	2,730	.....	984	.....	332	.....	284	.....	461	.....	234
Mean per square mile	.....	5.99	.....	2.16	.....	.728	.....	.623	.....	1.01	.....	.513
Run-off, depth in inches	.....	3.56	.....	2.41	.....	.84	.....	.72	.....	1.12	.....	.40

[a] The river was frozen over after October 21.

M'MANUS CREEK.

McManus Creek, the left fork of Chatanika River, rises between the headwaters of Birch Creek, a tributary of the Yukon, and the west fork of the Chena, a tributary of the Tanana. The ridges that surround it have a general elevation of about 3,000 feet. Its principal tributaries are Montana and Idaho creeks from the north, and Smith Creek which enters from the south near its mouth. Pool Creek is tributary to Smith Creek. One or two possible reservoir sites are found in this basin, but they are not as favorable as those on Faith Creek.

A gaging weir was established on McManus Creek near its mouth June 20, 1907, by the Chatanika Ditch Company, and records were kept until the weir was washed out on September 5. A number of miscellaneous measurements were also made.

Daily estimated discharge, in second-feet, of McManus Creek near mouth, 1907.

[Elevation, 1,375 feet; drainage area, 80 square miles.]

Day.	June.	July.	Aug.	Sept.	Day.	June.	July.	Aug.	Sept.
1		21.6	81.2	71.5	20	34.8	31.6	33.6	
2		20.1	80.8	62.8	21	34.8	26.0	32.2	
3		19.0	56.1	57.8	22	31.2	21.2	68.7	
4		18.5	51.2	57.2	23	34.8	17.8	50.3	
5		17.8	63.4		24	25.0	21.4	67.1	
6		16.1	60.6		25	21.7	19.1	81.2	
7		17.5	98.6		26	25.0	38.6	102.0	
8		17.8	84.3		27	24.3	29.1	92.6	
9		15.8	75.6		28	31.1	23.9	91.2	
10		15.0	77.8		29	26.0	21.8	114.0	
11		16.1	62.2		30	23.2	18.8	112.0	
12		15.0	49.8		31		16.7	94.1	
13		15.4	45.5						
14		17.8	40.0		Mean	28.5	21.4	66.4	
15		18.5	37.2		Mean per square mile	.356	.268	.830	
16		19.0	42.4		Run-off, depth in inches	.15	.31	.96	
17		21.6	39.0						
18		34.7	37.4						
19		40.0	34.7						

NOTE.—These discharges were measured by weir, and were furnished by the Chatanika Ditch Company.

Miscellaneous measurements in McManus Creek drainage basin, 1907–1908.

Date.	Point of measurement.	Elevation.[a]	Drainage area.	Discharge.	Discharge per square mile.
1907.		*Feet.*	*Sq. miles.*	*Sec.-ft.*	*Sec.-ft.*
July 10	McManus Creek at mouth	1,375	80	15.6	0.195
Do	do	1,375	80	16.4	.205
July 12	McManus Creek above Smith Creek	1,400	42.8	10.2	.243
Do	Smith Creek near mouth	1,400	34	7.8	.229
Do	McManus Creek at mouth	1,375	80	15.6	.192
July 13	McManus Creek ¾ mile above Montana Creek.	2,000	8	1.8	.162
Do	McManus Creek below Montana Creek.	1,975	10	3.8	.380
Do	McManus Creek 1½ miles below Idaho Creek.	1,800	26	6.5	.250
Do	McManus Creek ½ mile above mouth	1,390		[b] 21.4	
July 14	McManus Creek 500 feet above Smith Creek.	1,400	42	12.4	.296
Do	Smith Creek near mouth	1,400	34	8.7	.256
Do	Smith Creek above Pool Creek	1,450	17	5.4	.323
Do	Pool Creek above mouth	1,450	14	2.4	.172
Do	McManus Creek above mouth	1,380		[b] 19.4	
1908.					
July 14	McManus Creek at mouth	1,375	80	59.0	.738
Do	McManus Creek 500 feet above Smith Creek.	1,400	42	36.0	.858
July 12	Smith Creek below Pool Creek	1,400	34	33.8	.994
July 13	do	1,400	34	27.4	.806
July 14	do	1,400	34	22.7	.668
July 13	Smith Creek above Pool Creek	1,450	17	11.0	.647
July 14	do	1,450	17	9.3	.547
August 30	do	1,450	17	14.2	.835
September 1	do	1,450	17	20.5	1.21
July 12	Pool Creek at mouth	1,450	14	15.4	1.10
July 13	do	1,450	14	11.0	.786
July 14	do	1,450	14	12.3	.878

[a] Taken from topographic map of Fairbanks quadrangle; approximate only.
[b] Measurement approximate.

FAITH CREEK.

Faith Creek, the right fork of Chatanika River, has its source in the southeasterly slope of the high ridges separating the Beaver and Birch Creek drainage basin from that of the Chatanika. It occupies a rather narrow, irregular valley, very steep in its upper course, and drains an area of 51 square miles.

In the upper portion of the valley considerable ice remains as late as the middle of July, especially in Charity Creek. Below the mouth of Deep Creek, a tributary from the right in the lower valley, there is a favorable reservoir site and with a dam of moderate size a considerable amount of the flood waters could be stored.

The Chatanika Ditch Company established a gaging weir at the mouth of Faith Creek in 1907, and daily records were kept subsequent to June 21.

Daily estimated discharge, in second-feet, of Faith Creek near mouth, 1907.

[Elevation, 1,375 feet; drainage area, 51 square miles.]

Day.	June.	July.	Aug.	Sept.	Day.	June.	July.	Aug.	Sept.
1		32.6	36.4	59.0	20	44.7	43.9	27.8	
2		28.5	41.1	52.5	21	44.7	38.6	26.9	
3		26.4	35.9	50.2	22	42.8	31.4	44.2	
4		24.8	34.7	66.4	23	39.3	25.5	39.4	
5		22.1	42.5		24	38.8	28.8	49.8	
6		21.6	40.6		25	35.3	26.4	62.8	
7		22.0	87.4		26	36.5	61.0	82.6	
8		20.8	62.7		27	34.4	42.0	69.3	
9		20.1	52.4		28	45.9	28.4	62.6	
10		19.2	44.2		29	43.6	30.6	70.5	
11		21.0	39.0		30	36.8	26.7	72.5	
12		20.5	35.0		31		25.0	67.8	
13		20.1	42.8						
14		21.0	35.6		Mean	40.5	29.2	47.5	
15		20.9	33.6		Mean per square mile	.795	.572	.932	
16		21.7	34.4						
17		35.3	30.8		Run-off, depth in inches	.32	.66	1.07	
18		35.0	30.6						
19		62.5	28.5						

NOTE.—These discharges were measured by weir, and were furnished by the Chatanika Ditch Company.

Miscellaneous measurements in Faith Creek drainage basin, 1907–1908.

Date.	Point of measurement.	Elevation.	Drainage area.	Discharge.	Discharge per square mile.
1907.		*Feet.*	*Sq. miles.*	*Sec.-ft.*	*Sec.-ft.*
July 11	Hope Creek near Zephyr Creek			7.7	0.42
Do	Charity Creek near mouth			5.7	.76
1908.					
July 12	Faith Creek near mouth	1,375	51	66.9	1.31
July 13	do	1,375	51	77.7	1.52
July 14	do	1,375	51	67.7	1.33

KOKOMO CREEK.

Kokomo Creek, a tributary to Chatanika River from the left, about 28 miles below Faith Creek, rises in the high ridge at the head of Miller and Elliot creeks and flows northward, draining an area of 33 square miles. Daily readings were taken from a reference point in a large stump on the river bank above Alder Creek and about 1 mile above the mouth of the stream.

Discharge measurements of Kokomo Creek near mouth, 1907.

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
July 9	−3.00	13.9
August 14	−2.70	22.7

Daily gage height and estimated discharge of Kokomo Creek near mouth, 1907.

[Elevation, 750 feet; drainage, area 23 square miles.]

Day.	July.		August.		Day.	July.		August.	
	Gage height.	Discharge.	Gage height.	Discharge.		Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*		*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			+0.9	112	19	−3.0	13.9		
2			−1.2	68	20	−3.0	13.9		
3			−2.0	43.8	21	−3.0	13.9		
4			−2.2	37.9	22	−3.1	10.9		
5			−2.4	31.8	23	−3.2	7.9		
6			−2.4	31.8	24	−3.0	13.9		
7			−2.3	34.8	25	−3.1	1.09		
8			−2.4	31.8	26	−3.0	13.9		
9	−3.0	13.9	−2.0	43.8	27	−3.0	13.9		
10	−3.1	10.9	−2.2	37.9	28	−3.0	13.9		
11	−2.6	25.8	−2.4	31.8	29	−3.1	10.9		
12	−2.8	19.8	−2.5	28.9	30	−3.2	7.9		
13	−2.8	19.8	−2.6	25.8	31	−3.2	7.9		
14	−2.9	16.8	−2.7	22.7					
15	−2.9	16.8			Mean		14.2		41.6
16	−2.9	16.8			Mean per square mile		.546		1.00
17	−3.0	13.9			Run-off, depth in inches		.47		.83
18	−2.8	19.8							

POKER CREEK.

Poker Creek, with its tributary, Caribou Creek, rises in the high, barren ridges about Poker Dome and opposite the headwaters of Ophir, Trail, and Washington creeks. It drains an oval-shaped area of 40.5 square miles, well covered with timber, and has steep precipitous slopes in its upper course.

The Tanana Electric Company has constructed a ditch line along the left bank of Poker Creek, following approximately the 800-foot contour. This ditch diverts water from Poker, Little Poker, and Caribou creeks to a point on the Chatanika, where about 80 feet head is obtained. A power plant was installed at this point, in 1908, and is run by water when available, and by steam at other times.

Discharge measurements in Poker Creek drainage basin, 1907–1908.

Date.	Point of measurement.	Drainage area.	Gage height.	Discharge.	Discharge per square mile.
1907.		*Sq. miles.*	*Feet.*	*Sec.-ft.*	*Sec.-ft.*
July 27	Poker Creek near mouth	40	1.09	22.3	0.558
July 30	do	40	1.10	22.6	.565
August 9	do	40	1.32	36.6	.915
August 10	do	40	1.33	37.8	.944
Do	Caribou Creek above Little Poker Creek			10.4	
Do	Little Poker Creek near mouth			3.9	
Do	Poker Creek at elevation 800 feet	18.1		21.1	1.17
1908.					
August 14	do	18.1		9.3	.514
Do	Little Poker and Caribou Creek ditch			6.2	

CLEARY CREEK.

Cleary Creek heads to the north of Pedro Dome in a rather low saddle which separates its waters from those of Eldorado Creek and which has an elevation of about 1,800 feet. The creek flows in a northerly direction for about 3 miles, then, by a gradual curve to the left, takes a northwesterly course to Chatanika River, to which it is tributary from the left about 2 miles below Poker Creek.

The creek has an average slope of about 90 feet to the mile through the mining section. It is considered the best producer in the camp. (See Pl. III.) The pay streak follows the creek channel closely about to claim 15 below. At that point it swings to the left bank, which it follows to the Chatanika flats.

Cleary Creek has a drainage area of 10.5 square miles above its mouth.

Discharge measurements in Cleary Creek drainage basin, 1907–1908.

Date.	Point of measurement.	Drainage area.	Discharge.	Discharge per square mile.
1907.		*Sq. miles.*	*Sec.-ft.*	*Sec.-ft.*
July 4	Cleary Creek near Cleary		2.9	
1908.				
July 23	Cleary Creek above Wolf Creek	3.4	1.6	0.471
Do	Chatham Creek at mouth	3.0	1.3	.433
Do	Wolf Creek at mouth	3.8	.91	.240

ELDORADO CREEK.

Eldorado Creek rises on the western slope of Pedro Dome and drains a rather narrow valley between Cleary and Dome creeks. It has a steep slope in its upper portion. The average fall of the creek through the mining section is 115 feet per mile. It is about 5 miles long and drains an area of 13.7 square miles. The creek flows in a narrow, rather deep-cut channel, well lined with willows.

The pay streak is on the right bank and is located from claim 7 above to claim 4 below. Bed rock ranges from 90 to 122 feet below

MINING OPERATIONS ON CLEARY CREEK.

the surface, with 10 to 80 feet of gravel. The following measurement was made June 26, 1907: Discharge, 0.45 second-foot; elevation, 930 feet; drainage area, 4 square miles; discharge, 0.112 second-foot per square mile.

DOME CREEK.

Dome Creek rises in the Chatanika divide, opposite Steamboat and Flume creeks, and flows northward into Chatanika River. It is about 5 miles long and drains an area of 13.9 square miles. The creek has an average grade through the mining section of about 70 feet to the mile and good values are found in its upper and lower courses. Discovery claim is located on the right bank near the town of Dome. The creek is being worked on several claims from 7 above to 20 below. The pay streak is on the right bank for practically its entire length. Bed rock ranges from 40 feet below the surface in the upper portion of the drainage area to more than 200 feet below in the Chatanika flats, near the mouth of the stream. Very little water flows in the main channel during the low-water period, a large part of the flow being diverted by numerous small ditches. A measurement, made June 27, 1907, in a ditch near claim 2 below, gave an approximate discharge of 0.84 second-foot.

MISCELLANEOUS MEASUREMENTS.

Measurements were made of a number of small streams tributary to Chatanika River. Sourdough enters the river from the north about 3 miles below Faith Creek. Flat Creek is a small tributary from the south. Boston, Mackay, Belle, and Crooked creeks rise in the high ridge that separates their basins from the basin of Ophir Creek, a tributary of Beaver Creek, and enter the Chatanika from the north, about 25 miles below Faith Creek. They are 4 to 6 miles long and very steep, with deep, narrow valleys. Murphy Creek enters the river from the south near the lower end of the Chatanika flats.

Miscellaneous measurements in Chatanika River drainage basin, 1907–1908.

Date.	Point of measurement.	Elevation.	Drainage area.	Discharge.	Discharge per square mile.
1907.		*Feet.*	*Sq. miles.*	*Sec-ft.*	*Sec.-ft.*
August 15	Boston Creek	800	6.5	3.9	0.600
Do	Mackay Creek	800	6.2	3.7	.596
Do	Crooked Creek	800	7.2	6.3	.875
Do	Belle Creek	800	11.2	10.	.909
1908.					
August 9	....do	1,200	3.0	1.4	.467
July 13	Sourdough Creek near mouth		15.9	22.5	1.42
July 15	Flat Creek below 3d Pup		7.0	2.8	.400
August 29	....do		7.0	3.7	.529
July 26	Murphy Creek above McCloud Creek		17.0	1.7	.100
August 20	....do		17.0	1.3	.076
August 26	Chatanika River below Murphy Creek		814	263	.323

GOLDSTREAM CREEK DRAINAGE BASIN.

GENERAL DESCRIPTION.

Goldstream Creek flows southwestward, in a narrow, winding course, between the drainage basin of Chatanika River on the right and the Little Chena and Tanana basins on the left, paralleling Chatanika River, which it enters from the east, and draining the central portion of the Fairbanks mining district. It is about 70 miles long and it drains an area of about 500 square miles. About 40 miles below its source it leaves the dividing ridges and for the remainder of its course to the Chatanika flows in a zigzag channel across the soft, mucky flats northwest of Tanana River. The stream bed is sandy and shifting, and the channel is deeply cut in the alluvial soil that forms the bottom lands.

The dividing ridges rise about 1,000 feet above the stream bed and are well timbered with spruce and birch. On each side of the stream is a narrow lowland, with a gradual slope upward toward the ridges. This lowland is everywhere covered with the common moss, and where the valley widens, in its lower portion, lakes and swamps are numerous. The bottom land was once well covered with timber, but this has been removed to make way for the railroad and mining enterprises. About 12 miles below the source of the river the southern ridge is broken by a low saddle, over which the Tanana Valley Railroad from Fairbanks enters the mining district.

The upper portion of the valley is drained by Pedro and Gilmore creeks, which unite to form Goldstream Creek near Gilmore, about 12 miles north of Fairbanks.

Along Pedro Creek the pay streak follows the stream channel closely and bed rock is from 10 to 30 feet below the surface. On Goldstream Creek the pay streak is along the right bank to about claim 10 below and then swings to the left bank, which it follows to about claim 22 below. Farther than this it has not been definitely located. The depth to bed rock ranges from 20 to 60 feet.

Gilmore Creek, the left fork of Goldstream Creek, has shown small values and very little work is in progress. The creek has a fairly good grade and drains an area of 11.8 square miles.

Goldstream Creek receives numerous small tributaries from both sides. From the right come Fox, Gold Run, Big Eldorado, O'Connor, and Cache creeks; from the left, Engineer, Butter, Spear, Nugget, Straight, and Allen creeks. Prospecting and more or less mining is done on nearly all these creeks. They are from 4 to 12 miles long and drain small areas.

On the upper portion of Goldstream Creek and along Pedro Creek several small ditches have been built to divert water for sluicing. The largest ditch is owned by the Goldstream Ditch Company and

its construction cost about $6,500. It is about 2 miles long and has a fall of about 7 feet to the mile. It diverts water from claim 6 below, along the left bank of Goldstream Creek, and supplies several mines at the rate of $2 per hour per sluice head, which ranges from 60 to 80 miner's inches of water. A measurement made June 28, 1907, in the lower end of a flume near the intake to this ditch gave a discharge of 10.8 second-feet. A short extension was made to this ditch in 1908 and it now supplies water to mines as far as claim 16 below.

GOLDSTREAM CREEK AT CLAIM 6 BELOW.

A good location for a gaging station could not be found on Goldstream Creek because of the unfavorable condition of the channel and the numerous small ditches that divert the flow. A gage was established, however, near the lower line of claim 6 below, a short distance above the intake to the Goldstream ditch, June 20, 1907, and was read twice each day by John L. Meder. The water diverted by a small ditch a short distance above the gaging station is not considered in the table of estimates. Several measurements made in this ditch gave an average discharge of 1.5 second-feet.

Discharge measurements of Goldstream Creek at claim 6 below, 1907.

Date.	Width.	Area of section.	Gage height.	Discharge.
	Feet.	*Sq. ft.*	*Feet.*	*Sec.-feet.*
June 21	11.3	8.1	1.00	10.8
June 28	12.4	10.3	1.31	21.1

Daily mean gage height and estimated discharge of Goldstream Creek at claim 6 below, 1907.

[Elevation, 870 feet; drainage area, 28.6 square miles.]

Day.	June.		July.		August.		September.		October.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1	.....	.....	1.3	20.7	1.55	30.2	1.25	18.9	1.3	20.7
2	.....	.....	1.05	12.3	1.6	32.2	1.20	17.1	1.3	20.7
3	.....	.....	1.0	10.8	1.3	20.7	1.20	17.1	1.4	24.4
4	.....	.....	.95	9.3	1.15	15.4	1.25	18.9	1.3	20.7
5	.....	.....	.8	4.9	1.1	13.8	1.30	20.7	1.3	20.7
6	.....	.....	.75	3.6	1.15	15.4	1.2	17.1	1.3	20.7
7	.....	.....	1.15	15.4	1.4	24.4	1.2	17.1	1.2	17.1
8	.....	.....	1.05	12.3	1.45	26.3	1.15	15.4	.....	.....
9	.....	.....	1.0	10.8	1.35	22.5	1.2	17.1	.....	.....
10	.....	.....	.85	6.4	1.6	32.2	1.15	15.4	.....	.....
11	.....	.....	1.6	32.2	1.45	26.3	1.35	22.5	.....	.....
12	.....	.....	1.55	30.2	1.15	15.4	1.7	36.6	.....	.....
13	.....	.....	1.2	17.1	1.1	13.8	1.7	36.6	.....	.....
14	.....	.....	1.1	13.8	1.05	12.3	1.5	28.2	.....	.....
15	.....	.....	1.65	34.4	1.05	12.3	1.5	28.2	.....	.....

Daily mean gage height and estimated discharge of Goldstream Creek at claim 6 below, 1907—Continued.

Day.	June.		July.		August.		September.		October.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
16	.....	.....	1.5	28.2	1.1	13.8	1.8	41	.....	.....
17	.....	.....	1.25	18.9	1.0	10.8	1.55	30.2	.....	.....
18	.....	.....	1.15	15.4	1.0	10.8	1.45	26.3	.....	.....
19	.....	.....	1.05	12.3	1.0	10.8	1.3	20.7	.....	.....
20	1.0	10.8	1.05	12.3	1.1	13.8	1.6	32.2	.....	.....
21	1.0	10.8	1.0	10.8	1.25	18.9	1.45	26.3	.....	.....
22	.95	9.3	.95	9.3	1.3	20.7	1.4	24.4	.....	.....
23	.8	4.9	.9	7.8	1.3	20.7	1.55	30.2	.....	.....
24	.9	7.8	1.05	12.3	1.3	20.7	1.45	26.3	.....	.....
25	.9	7.8	.95	9.3	1.25	18.9	1.4	24.4	.....	.....
26	1.05	12.3	.95	9.3	1.35	22.5	1.4	24.4	.....	.....
27	.85	6.4	.85	6.4	1.3	20.7	1.3	20.7	.....	.....
28	1.3	20.7	.85	6.4	1.35	22.5	1.25	18.9	.....	.....
29	1.55	30.2	.8	4.9	1.45	26.3	1.35	22.5	.....	.....
30	1.45	26.3	.8	4.9	1.5	28.2	1.4	24.4	.....	.....
31	.....	.....	.7	2.2	1.5	28.2	.....	.....	.....	.....
Mean	.....	13.4	.....	13.1	.....	20.0	.....	24.0	.....	20.7
Mean square mile	.....	.469	.....	.458	.....	.699	.....	.839	.....	.724
Run-off, depth in inches	.....	.192	.....	.53	.....	.81	.....	.94	.....	.19

NOTE.—These discharges do not include the amount diverted at claim 3 below by a small ditch, carrying from 1 to 1.5 second-feet. The creek was frozen after October 7.

PEDRO CREEK.

Pedro Creek, the right fork of Goldstream Creek, is about 6 miles long and has a fall of 100 to 200 feet to the mile in its upper course. About 3 miles from its source Twin Creek, a tributary from the right, enters. Here in 1902 gold was first found in the Fairbanks district by Felix Pedro. Below this point the creek has a grade of about 80 feet to the mile, which gradually lessens as it approaches Goldstream Creek. The following measurement was made at claim 1 above July 22, 1908: Discharge, 3.2 second-feet; drainage area, 6.3 square miles; discharge per square mile, 0.508 second-foot.

FOX CREEK.

Fox Creek rises in the Chatanika divide opposite Vault Creek. It is about 3½ miles long and flows southward through a V-shaped valley into Goldstream Creek. Considerable mining activity was under way in 1908. The following measurements were made at elevation 900 feet: July 6, 1907, 2.0 second-feet; August 24, 1908, 0.43 second-foot.

WASHINGTON CREEK DRAINAGE BASIN.

GENERAL DESCRIPTION.

Washington Creek rises in the southern slope of the dividing ridge south of Beaver Creek drainage, and flows southwestward into Tatalina River about 12 miles above the confluence of that stream with the Tolovana. It parallels the Chatanika, from which it is separated at a distance of about 6 miles, by a high dividing ridge. The creek is about 35 miles long and drains an area of 198 square miles. It is shown on the reconnaissance map of the Fairbanks quadrangle.

The valley is long and narrow, is well timbered, and is bordered on each side by high ridges, portions of which are from 1,200 to 1,800 feet above the stream bed.

Late in the fall of 1907 rumors of a strike on Washington Creek attracted some attention and during the winter of 1907–8 considerable work was done on this creek, not only in prospecting, but in staking new ground. The summer of 1908 found the creek staked from its headwaters to within a few miles of its mouth.

Aggie Creek, which enters Washington Creek about 12 miles above its mouth, is its only important tributary. This stream is about 12 miles long and drains an area of 35.8 square miles.

A fall of about 200 feet in 8 miles on Washington Creek below Aggie Creek affords opportunity for power development. In 1908 the break-up on Washington Creek occurred about May 5, but there was considerable ice in the stream until after May 9, and the water could not have been used in a diverting ditch until about May 20.

WASHINGTON CREEK ABOVE AGGIE CREEK.

This station was established May 23, 1908, about 500 feet above the mouth of Aggie Creek, on the left-hand side of the stream. The gage, known as gage No. 2, was fastened to a wooden trestle under the footbridge constructed for high-water measurements. The bench mark is the top of a stake about 6 inches above ground, 10 feet from low-water mark on the left-hand side of the stream, and 4 feet above gage datum.

Discharge measurements of Washington Creek above Aggie Creek, 1908.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*		*Feet.*	*Sec.-feet.*
May 23	3.65	311.0	July 28	2.10	19.3
May 24	3.60	304.0	August 19	2.10	17.3
July 27	2.08	18.2			

Daily mean gage height and estimated discharge of Washington Creek above Aggie Creek, 1908.

[Elevation, 600 feet; drainage area, 117 square miles.]

Day.	May.		June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			3.45	266		45	2.15	22	2.25	30
2			3.22	203		45	2.18	24	2.32	38
3			3.00	146		45	2.25	30	2.58	67
4			2.95	135	2.40	45	2.20	26	2.80	104
5			2.82	109	2.40	45	2.20	26		
6			3.38	245	2.35	40	2.18	24		
7			3.38	245	2.40	45	2.15	22		
8			3.08	163	2.50	57	2.15	22		
9			2.90	124	2.55	63	2.15	22		
10			2.68	82	2.45	51	2.15	22		
11			2.55	63	2.38	43	2.15	22		
12			2.48	54	2.32	37	2.15	22		
13			2.62	74	2.20	26	2.15	22		
14			2.62	74	2.20	26	2.15	22		
15			4.50	557	2.25	30	2.15	22		
16			3.75	342	2.20	26	2.15	22		
17			3.32	231	2.20	26	2.15	22		
18			3.00	146	2.22	28	2.20	26		
19			3.20	196	2.22	28	2.15	22		
20			3.22	203	2.20	26	2.22	28		
21			3.10	170	2.20	26	2.20	26		
22			3.78	359	2.18	24	2.22	28		
23	3.65	316	3.12	176	2.10	18	2.22	28		
24	3.65	316	2.82	109	2.15	22	2.20	26		
25	3.45	266	2.60	70	2.15	22	2.15	22		
26	3.20	196	2.40	45	2.15	22	2.20	26		
27	3.15	183	2.42	48	2.15	22	2.20	26		
28	3.35	236		48	2.20	26	2.20	26		
29	3.50	278		48	2.22	28	2.25	30		
30	4.00	408		48	2.15	22	2.25	30		
31	3.75	342			2.15	22	2.20	26		
Mean		282		159		33.2		24.6		59.8
Mean per square mile		2.41		1.36		.284		.210		.512
Run-off, depth in inches		.81		1.52		.33		24		.08

WASHINGTON CREEK BELOW AGGIE CREEK.

This station was established May 5, 1908, by E. J. Burger for Martin Harrais, manager of the Chena Lumber and Light Company, of Chena, to determine the possibility of using the stream for the development of power. Gage No. 1, first installed, was replaced May 24 by gage No. 4, which is located about 500 feet below the mouth of Aggie Creek, on the left bank, and is referred to a spike driven in a notch cut at the base of the stream side of a cottonwood tree about 10 inches in diameter and 10 feet back from the edge of the bank; the top of the spike is 9.9 feet above the gage datum.

Theoretically the discharge at gage No. 4 should represent the totals at Nos. 2 and 3, but this is not always the case, for during high water a small stream from the left bank discharges between the gages, and in

the low-water period there is more or less seepage through the gravel. The records check very closely, however, and probably give very nearly the actual discharge of the creek during the season.

Discharge measurements of Washington Creek below Aggie Creek, 1908.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*		*Feet.*	*Sec.-feet.*
May 23	3.30	419	July 28	1.85	27.0
May 24	3.35	440	August 18	1.80	25.9
July 27	1.80	25.8	August 19	1.80	25.6

Daily mean gage height and estimated discharge of Washington Creek below Aggie Creek, 1908.

[Elevation, 600 feet; drainage area, 147 square miles.]

Day.	May.[a]		June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			3.12	332		53	1.80	28	1.95	38
2			3.00	284		53	1.84	31	2.06	49
3			2.75	185		53	1.92	37	2.32	82
4			2.70	166	2.10	52	1.86	33	2.55	124
5		840	2.62	141	2.10	52	1.85	32		
6		720	2.98	279	2.05	48	1.80	28		
7		760	2.96	274	2.11	53	1.80	28		
8		880	2.78	194	2.24	69	1.80	28		
9		920	2.64	149	2.30	88	1.80	28		
10		1,200	2.45	104	2.18	61	1.80	28		
11		760	2.32	80	2.18	61	1.80	28		
12		688	2.25	70	2.05	48	1.80	28		
13		1,120	2.38	89	1.86	33	1.80	28		
14		1,160	2.42	98	1.85	32	1.80	28		
15		1,400	3.66	600	1.92	37	1.80	28		
16		1,280	3.18	360	1.87	34	1.80	28		
17		1,240	2.91	246	1.87	34	1.80	28		
18		1,160	2.68	160	1.91	36	1.85	32		
19		1,040	2.82	210	1.91	36	1.80	28		
20		1,120	2.84	218	1.88	34	1.88	34		
21		840	2.75	185	1.85	32	1.85	32		
22		490	3.22	375	1.83	30	1.88	34		
23	3.10	328	2.76	188	1.75	24	1.88	34		
24	3.35	440	2.52	118	1.82	30	1.85	32		
25	3.18	352	2.30	77	1.81	29	1.80	28		
26	2.92	250	2.10	52	1.80	28	1.86	33		
27	2.88	234	2.15	58	1.80	28	1.86	33		
28	3.06	310		56	1.90	35	1.86	33		
29	3.20	370		56	1.90	35	1.92	37		
30	3.52	525		56	1.79	27	1.92	37		
31	3.40	465			1.78	26	1.86	33		
Mean		774		182		41.3		30.8		73.1
Mean per square mile		5.26		1.23		.281		.210		.498
Run-off, depth in inches		5.28		1.37		.324		.24		.07

[a] Discharges from May 5 to 22, inclusive, are based on readings from gage No. 1, and on account of unfavorable channel conditions are approximate.

AGGIE CREEK AT MOUTH.

This station was established May 23, 1908. The gage, known as "gage No. 3," is located on the right bank about 1,000 feet above the mouth of the stream. It is referred to a spike driven in the top of a stump about 5 feet farther downstream on the same side; the top of the spike is 6.10 feet above the datum of the gage.

Discharge measurements of Aggie Creek at mouth, 1908.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*		*Feet.*	*Sec.-feet.*
May 23	2.92	108.0	July 28	1.09	8.8
May 24	3.29	136.0	August 19	.90	7.0
July 27	.95	6.3			

Daily mean gage height and estimated discharge of Aggie Creek at mouth, 1908.

[Elevation, 600 feet; drainage area, 35.8 square miles.]

Day.	May.		June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1	.....	.....	2.30	65	.....	7.5	.92	6.2	1.08	8.5
2	.....	.....	2.50	79	.....	7.5	1.00	7.5	1.18	10.6
3	.....	.....	1.80	36	.....	7.5	1.00	7.5	1.30	14.0
4	.....	.....	1.72	31	1.00	7.5	.98	7.0	1.35	16.0
5	.....	.....	1.80	36	1.00	7.5	.95	6.5	.....	.....
6	.....	.....	1.78	34	1.02	7.8	.92	6.2	.....	.....
7	.....	.....	1.65	28	1.05	8.0	.90	6.0	.....	.....
8	.....	.....	1.75	34	1.17	11.0	.90	6.0	.....	.....
9	.....	.....	1.58	24	1.30	14.0	.90	6.0	.....	.....
10	.....	.....	1.47	20	1.07	9.5	.90	6.0	.....	.....
11	.....	.....	1.40	17	1.10	9.0	.90	6.0	.....	.....
12	.....	.....	1.38	16	1.02	7.8	.90	6.0	.....	.....
13	.....	.....	1.32	14	.98	7.0	.90	6.0	.....	.....
14	.....	.....	1.55	23	.98	7.0	.90	6.0	.....	.....
15	.....	.....	1.90	41	.98	7.0	.90	6.0	.....	.....
16	.....	.....	1.50	21	1.02	7.8	.90	6.0	.....	.....
17	.....	.....	1.35	16	1.02	7.8	.90	6.0	.....	.....
18	.....	.....	1.30	14	1.00	7.5	.90	6.0	.....	.....
19	.....	.....	1.30	14	1.00	7.5	.90	6.0	.....	.....
20	.....	.....	1.30	14	1.00	7.5	.90	6.0	.....	.....
21	.....	.....	1.30	14	1.00	7.5	.90	6.0	.....	.....
22	.....	.....	1.35	16	.95	6.5	.90	6.0	.....	.....
23	2.90	107	1.17	11	.95	6.5	.90	6.0	.....	.....
24	3.15	125	1.15	10	1.00	7.5	.90	6.0	.....	.....
25	2.60	86	1.05	8.0	.98	7.0	.90	6.0	.....	.....
26	2.06	50	1.07	8.5	.95	6.5	.95	6.5	.....	.....
27	2.05	50	1.02	7.8	.95	6.5	.95	6.5	.....	.....
28	2.40	72	.....	7.8	1.05	8.0	.95	6.5	.....	.....
29	2.67	91	.....	7.8	.98	7.0	.95	6.5	.....	.....
30	3.02	116	.....	7.8	.88	5.0	.95	6.5	.....	.....
31	3.12	123	.....	.....	.85	4.5	.95	6.5	.....	.....
Mean	.....	91.2	.....	22.5	.....	7.58	.....	6.26	.....	12.2
Mean per square mile	.....	2.55	.....	.629	.....	.211	.....	.174	.....	.341
Run-off, depth in inches	.....	.85	.....	.70	.....	.24	.....	.20	.....	.05

BEAVER CREEK DRAINAGE BASIN.

GENERAL DESCRIPTION.

A high limestone ridge—the White Mountains—50 miles north of Fairbanks, is perhaps the highest portion of the divide between the Yukon and Tanana drainage basins. Beaver Creek, which drains the largest part of this particular portion of the divide, has its source far back in the deep canyons of the southern slope. There are two branches of Beaver Creek in its upper drainage basin that join at about latitude 65° 25′ north, and longitude 147° west. These two branches drain the highest portion of the mountains. The southern branch rises in a high ridge opposite the tributaries of Preacher Creek. It has a steep and tortuous course, flowing over a rocky bed and through a deep valley. The northern or main branch of Beaver Creek drains to the south the central portion of the mountain ridge. The gorgelike valley of the upper portion of this branch runs in an east-west direction and forms with the main valley a letter T. The course of the northern branch is tortuous and the bed is rough and gravelly. In the valley at the junction of these two branches some timber is found, and there are also small patches of meadow land. From the junction the main stream flows westward for about 25 miles, then makes an abrupt bend to the right and flows in a northeasterly direction, draining the northern slope of the White Mountains. Its course above the "big bend" is through a rather broad, parklike valley, over a wide gravelly bed, in a series of riffles and pools. This portion of the stream, with its tributaries, drains the southern slope of the White Mountains. In many places the stream has several channels, forming numerous islands which are usually covered with a heavy growth of timber.

Bear and Bryan creeks are the important tributaries from the right. High, barren limestone ridges separate these creeks and form deep, narrow, gorgelike valleys, through which the streams flow over precipitous, narrow beds.

There is but little timber on the slopes of the mountains except in the lower course of the stream, and here the average size is smaller than that of the timber in the Chatanika and Little Chena basins.

The southern tributaries of Beaver Creek above the big bend are Nome, Ophir, Trail, and Wickersham creeks, whose upper portions drain the dividing ridge to the north of Chatanika River. These streams have more gradual slopes than the northern tributaries, and flow through rather narrow channels cut deep into the soft, alluvial soil of which their bottom lands consist. The ridges separating these creeks are at a much lower elevation than those on the northern slope.

81007—IRR 228—09——4

They are covered with timber and the many small streams which drain their slopes are fed by numerous springs. The general direction of these streams, with the exception of Nome Creek, is to the northwest—a course almost opposite that of the main creek which receives their black, tranquil waters.

The upper portion of the Beaver Creek drainage basin is oval in shape and rises to an elevation of 1,800 to 4,000 feet. A portion of the easterly divide has an altitude of 5,000 feet. About 8 miles below the "big bend" Fossil Creek enters Beaver Creek from the right through a deep, narrow canyon. It drains a long, narrow, rather high valley and rises on the northern slope of Cache Mountain, which has an elevation of over 4,000 feet and separates the Fossil Creek drainage basin from that of Bryan Creek. Fossil Creek flows northward for 5 or 6 miles, makes a long, easy curve to the left, flows around the northern foothills, and finally takes a southwesterly course close to the high limestone ridge that separates it from Beaver Creek.

In the upper portion of the Fossil Creek basin, on the right-hand side, there is a marked case of stream piracy. A small stream reaches into the right-hand part of the basin and takes a portion of the drainage through a gorge of high elevation into Beaver Creek, about 12 miles below the mouth of Fossil Creek.

Victoria Creek, a tributary from the left about 20 miles below Fossil Creek, has its source nearly opposite Cache Mountain and is separated from Beaver Creek, which it parallels for about 50 miles, by a limestone ridge ranging from 1,000 to nearly 3,000 feet above the bed of the stream.

Some distance below the mouth of Victoria Creek, Beaver Creek changes its course to the left and flows in a northwesterly direction through a less mountainous country to the Yukon.

Beaver Creek has every indication of furnishing a good water supply. Its high drainage basin makes its waters desirable for either hydraulicking or power development. Although the present location of the mining camps is at a prohibitive distance for ditch lines, future developments may make valuable any information concerning the daily flow and run-off in this drainage basin.

MEASUREMENTS.

The following miscellaneous measurements were made in Beaver Creek drainage basin:

Miscellaneous measurements in Beaver Creek drainage basin, 1907–1908.

Date.	Stream and locality.	Approximate elevation.	Drainage area.	Discharge.	Discharge per square mile.
1907.		*Feet.*	*Sq. miles.*	*Sec.-ft.*	*Sec.-ft.*
August 27	Trail Creek	1,700	27	39.9	1.48
Do	Brigham Creek	1,500	15	16.0	1.06
August 28	Fossil Creek	1,300	.....	19.2	.....
August 29	Bryan Creek	1,800	48	75.3	1.57
August 30	Beaver Creek above East Branch	1,800	122	267	2.19
Do	East Branch Beaver Creek above mouth	1,800	67	124	1.85
Do	Nome Creek near mouth	1,700	120	135	1.12
1908.					
August 11	Beaver Creek above East Branch	1,800	122	80.3	.658
August 12	Beaver Creek above Nome Creek	1,675	226	108	.478
August 11	East Branch of Beaver Creek at mouth	1,800	67	44.3	.661
August 12	Nome Creek near mouth	1,700	120	33.6	.280
Do	Nome Creek above Ophir Creek	1,725	87	26.0	.299
Do	Ophir Creek near mouth	1,725	33	2.0	.066

THE CIRCLE DISTRICT.

DESCRIPTION OF AREA.

The area to the north of the Yukon-Tanana divide, between latitude 143° 40′ and 146° 50′, is known as the Birch Creek region of the Circle district. Generally speaking, it occupies two geographic divisions—a low, broad, alluvial plain and a high plateau.

The northwest portion of the low broad plain forms the bottom lands of the Yukon Flats north of Crazy Mountains; the southeast portion occupies an irregular area surrounded by a low ridge along the Yukon, the Crazy Mountains, and the range of hills 20 to 40 miles farther south. This portion is cut by Birch and Crooked creeks; it is well timbered along these streams and contains large areas of meadow-like swamp land that furnish forage for both summer and winter use.

The plateau division, whose longest diameter is east and west, occupies a position between two distinct ridges—the eastern extensions of the White Mountains. The ridge to the south is high and barren and forms the main Yukon-Tanana divide; that to the north is lower, irregular, and barren, and separates the upper tributaries of Birch Creek drainage from the lower, and it is itself divided by the deep canyon-like gorge through which Birch Creek flows on its way to the Yukon.

At elevations of 2,000 feet or more above sea level the country is as a rule barren and rocky, while below this altitude, especially in the flats where Birch and Crooked creeks join, considerable timber is found. These flats afford conditions particularly favorable to agriculture as well as to mining. At Central House, on the lower end of Deadwood Creek, and at the Hot Sulphur Springs all kinds of vege-

tables grow in abundance; and prospecting at the lower end of Deadwood Creek shows an extensive area of ground which seems suitable for dredging.

Circle, about 140 miles below Eagle, on the left bank of the Yukon, is the supply point for mines in this region, which are reached by sleds in winter and by pack train in summer. It is at Circle that the overland trail to the Fairbanks district, south of the divide, starts. In 1908 the Alaska Road Commission constructed about 20 miles of good wagon road along this trail, and expects to continue it to Miller House during the coming season.

GAGING STATIONS.

The following is a list of the points in the Circle district at which gages were established or measurements made in 1908. The numbers refer to Plate IV.

Gaging stations in Circle district, 1908.

1. Birch Creek at Fourteenmile House.
2. North Fork of Birch Creek above Twelvemile Creek and Twelvemile Creek at mouth.
3. North Fork of Birch Creek below Twelvemile Creek.
4. Eagle Creek below Mastodon Fork.
5. Eagle Creek below Cripple Creek.
6. Eagle Creek at mouth.
7. Miller Fork above ditch intake and Miller Fork ditch at intake.
8. Mastodon Fork above storage dam and Miller Fork ditch at outlet.
9. Ptarmigan Creek at mouth.
10. Tributary of North Fork of Birch Creek.
11. Twelvemile Creek at elevation of 2,500 feet.
12. Twelvemile Creek above East Fork.
13. East Fork of Twelvemile Creek near mouth.
14. Harrison Creek at elevation 2,200 feet.
15. North Fork of Harrison Creek at elevation 2,200 feet.
16. Crooked Creek at Central House.
17. Mammoth Creek at Miller House.
18. Mastodon Creek at claim 21 above.
19. Mastodon Creek at claim 1 above.
20. Independence Creek near mouth.
21. Miller Creek near mouth.
22. Porcupine Creek near proposed ditch intake.
23. Porcupine Creek below Bonanza Creek.
24. Bonanza Creek at ditch intake.
25. Boulder Creek near mouth.
26. Deadwood Creek above Switch Creek.
27. Switch Creek at mouth.
28. Albert Creek at trail crossing.
29. Quartz Creek at trail crossing.

MAP SHOWING LOCATION OF GAGING STATIONS IN CIRCLE DISTRICT.

BIRCH CREEK DRAINAGE BASIN.

GENERAL DESCRIPTION.

Birch Creek, with its tributaries, North and South forks, and their many ramifying branches, drains the southern part of the plateau country of the Circle district.

Crooked and Preacher creeks, which join Birch Creek in its lower course, drain the north slope of the ridge which separates the upper from the lower Birch Creek drainage, the Crazy Mountains, and a large portion of the broad alluvial plain. The main stream rises east of the headwaters of Chatanika River, and flows eastward to within less than 20 miles of the Yukon; it then turns to the north and flows roughly parallel to the main river to its mouth below Fort Yukon.

BIRCH CREEK AT FOURTEENMILE HOUSE.

A gaging station was established on Birch Creek at Fourteenmile House June 27, 1908. A post gage, graduated to feet and tenths and driven firmly in the ground on the left bank, was read twice each day during the remainder of the season by William Reger, road-house keeper and ferryman. Measurements are made from a ferry established by the Alaska Road Commission. Birch Creek at this point has a straight course for nearly 1,000 feet above and below the gage. The bed is gravelly and permanent. The left bank is steep and is seldom flooded except in extreme high water. The right bank is lower, somewhat timbered, and is more frequently overflowed.

Discharge measurements of Birch Creek at Fourteenmile House, 1908.

Date.	Area of section.	Mean velocity.	Gage heighth.	Discharge.
	Sq. feet.	*Ft. per sec.*	*Feet.*	*Sec.-feet.*
June 27	655	1.62	3.17	1,060
June 28	653	1.60	3.07	1,040
September 11	960	2.15	4.00	2,060
September 12	870	1.97	3.82	1,710

Daily mean gage height and estimated discharge of Birch Creek at Fourteenmile House, 1908.

[Elevation, 700 feet; drainage area, 2,150 square miles.]

Day.	June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			3.38	1,210	2.62	875	3.58	1,400
2			3.10	1,040	2.55	859	3.70	1,550
3			3.00	990	2.50	847	4.08	2,210
4			3.32	1,170	2.50	847	5.55	5,130
5			3.05	1,010	2.50	847	6.02	6,070
6			2.98	984	2.48	842	5.75	5,530
7			3.15	1,060	2.45	835	5.25	4,530
8			3.92	1,900	2.40	825	5.02	4,070
9			4.30	2,630	2.42	829	4.85	3,730
10			4.22	2,470	3.52	1,320	4.32	2,670

Daily mean gage height and estimated discharge of Birch Creek at Fourteenmile House, 1908—Continued.

Day.	June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
11			3.75	1,620	3.45	1,270	4.00	2,060
12			3.45	1,270	3.25	1,120	3.88	1,830
13			3.28	1,140	3.12	1,040	3.72	1,580
14			3.12	1,040	3.00	990	3.68	1,520
15			3.02	1,000	2.92	966	3.65	1,480
16			3.02	1,000	2.90	960	3.60	1,420
17			3.10	1,040	2.85	945	3.55	1,360
18			3.05	1,010	2.88	954	3.55	1,360
19			3.00	990	2.90	960	3.62	1,440
20			2.92	966	2.95	975	3.72	1,580
21			2.82	936	3.00	990	3.62	1,440
22			2.72	906	3.18	1,080	3.52	1,320
23			2.62	875	3.70	1,550	3.35	1,190
24			2.58	867	3.55	1,360	3.18	1,080
25			2.52	852	3.45	1,270	3.08	1,030
26	3.35	1,190	2.50	847	3.45	1,270	3.00	990
27	3.20	1,090	2.62	875	3.42	1,250	2.88	954
28	3.10	1,040	2.65	885	3.35	1,190	2.78	924
29	3.08	1,020	2.62	875	3.52	1,330	2.70	900
30	3.20	1,090	2.60	872	3.82	1,620		
31			2.65	885	3.68	1,520		
Mean		1,090		1,140		1,080		2,150
Mean per square mile		.507		.530		.502		1.00
Run-off, depth in inches		.09		.61		.58		1.08

NOTE.—The creek was frozen after September 29.

NORTH FORK OF BIRCH CREEK.

North Fork of Birch Creek is formed by the confluence of Eagle and Ptarmigan creeks and flows southwestward through an unsymmetrical valley, flanked on both sides by high precipitous ridges, those to the north rising to an elevation of 2,000 feet to 2,500 feet above the stream bed in a distance of 5 to 6 miles.

Considerable timber, a large portion of which has reached a size suitable for milling, grows along the creek bottom. About 8 miles below Eagle Creek, North Fork turns abruptly to the left, and Twelvemile Creek, a tributary from the right, enters. The grade of these two streams above this point ranges from 75 feet to over 100 feet to the mile.

Much prospecting has been done, especially on Twelvemile Creek, where bed rock lies from 12 to 20 feet below surface, but on account of underground water very little is known of the bed rock conditions. North Fork enters Birch Creek about 8 miles below Twelvemile.

Eagle Creek is formed by the confluence of Miller and Mastodon forks, which drain the western slope of the high ridge connecting Mastodon and Porcupine domes, whose eastern drainage is carried

into Miller and Mastodon creeks. The creek is about 4 miles long and, with Ptarmigan, forms the North Fork of Birch Creek. Gold was discovered on Eagle Creek in 1895, and much work has been done at its upper end and on Mastodon Fork. In 1908 Berry and Lamb completed the installation of a hydraulic plant. (See Pl. V, *A*.)

The following measurements were made of North Fork and its tributaries:

Miscellaneous measurements of North Fork of Birch Creek and tributaries, 1908.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		Sq. miles.	*Sec.-ft.*	*Sec.-ft.*
July 10	North Fork of Birch Creek above Twelvemile Creek	87	87	1.00
September 4	do	87	191	2.20
July 9	North Fork of Birch Creek below Twelvemile Creek	132	125	.947
July 10	do	132	129	.977
September 6	Eagle Creek below Mastodon Fork	8.4	[a]4.2	.....
July 7	Eagle Creek below Cripple Creek	12.4	10.5	.847
July 9	Eagle Creek at mouth	15.5	15.4	.994
September 5	do	15.5	24.7	1.59
September 6	Miller Fork of Eagle Creek above ditch intake	2.6	2.1	.808
Do	Miller Fork ditch at intake	.....	2.8	.....
Do	Miller Fork ditch at outlet	.....	1.4	.....
July 7	Mastodon Fork of Eagle Creek above storage dam	4.1	1.1	.28
September 6	do	4.1	1.3	.317
July 9	Ptarmigan Creek at mouth	19	26.2	1.38
September 5	do	19	24.7	1.30
July 9	Tributary of North Fork of Birch Creek from north near mouth.	11.6	20.3	1.75
July 10	Twelvemile Creek at elevation 2,500 feet	1.6	6.3	3.94
July 11	do	1.6	6.0	3.75
Do	Twelvemile Creek above East Fork	18.9	15.6	.825
Do	Twelvemile Creek at mouth	44.5	38	.855
September 4	do	44.5	73.3	1.64
July 10	East Fork Twelvemile Creek near mouth	22.9	24.4	1.07
September 4	do	22.9	23.9	1.04

[a] Some water was diverted past section in the ditch from Miller and Mastodon forks; this measurement shows the seepage from the diversion dams and ditch.

HARRISON CREEK.

Harrison Creek, tributary to Birch Creek from the north near the junction of the South Fork, drains a narrow, irregular, V-shaped valley south of the divide at the head of Independence, Boulder, and Deadwood creeks. The North Fork of this stream, which heads against Mastodon Dome, was the scene of the first hydraulicking in the Birch Creek region, though on account of miscalculations the venture proved a failure.

The following measurements were made on this stream in 1908: July 8, Harrison Creek, elevation, 2,200 feet; discharge, 4.9 second-feet; drainage area, 17.9 square miles; discharge, 0.274 second-foot per square mile. July 8, North Fork, elevation, 2,600 feet; discharge, 7.1 second-feet; drainage area, 6.2 square miles; discharge, 1.15 second-feet per square mile.

CROOKED CREEK.

Over the divide to the north, Crooked Creek, with its fan-shaped drainage basin, gathers the waters of Porcupine and Mastodon domes. Porcupine and Mammoth creeks form this stream which, after leaving the hills, meanders through a rather broad valley for about 30 miles, discharging its waters into Birch Creek about 10 miles above Fourteenmile House. Boulder and Deadwood creeks are tributaries from the south.

The following miscellaneous measurements were made in Crooked Creek drainage basin in 1908:

Measurements in Crooked Creek drainage basin, 1908.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		Sq. miles.	*Sec.-feet.*	*Sec.-feet.*
June 30	Crooked Creek at Central House	161	57.7	0.358
July 1	do	161	52.0	.323
September 9	do	161	86.4	.536
July 1	Albert Creek at trail crossing		9.1	
Do	Quartz Creek at trail crossing	8.4	2.7	.322

MAMMOTH CREEK.

Mammoth Creek, which with Porcupine Creek forms Crooked Creek, is itself formed by the confluence of Mastodon and Independence creeks. These creeks, with Miller Creek, drain the area between Bonanza and Boulder creeks. Mastodon and Independence creeks head on the northern slope of Mastodon Dome, flow northwestward about 6 miles, and unite to form Mammoth Creek. Mastodon Creek Valley is V-shaped and is flanked on either side by even-topped ridges having a gentle slope parallel to that of the stream and about 1,300 feet above its bed. Independence Creek has an unsymmetrical valley with the steep slope on the left, the right side being cut by numerous small tributaries. Both streams flow in rather loose gravelly beds, and their valleys are sparsely timbered and very steep in their upper courses. Considerable mining has been done on these creeks, especially on Independence, where operations were active in 1908. Miller Creek rises in the ridge between Porcupine and Mastodon domes and flows northeastward to Mammoth Creek. Some mining has been done on this creek.

A gaging station was established on Mammoth Creek at Miller House, July 2, 1908. The gage is nailed to a log retaining wall on the left bank of the stream just below the bridge, and is referred to a spike driven in a log at the upstream end of the road house, marked B. M.; the spike is 10.17 feet above zero of gage. Readings were taken by J. F. Kelly, merchant, at Miller House.

Discharge measurements of Mammoth Creek at Miller House, 1908.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*		*Feet.*	*Sec.-feet.*
July 2	0.85	33.7	September 6	0.90	34.9
July 6	.70	20.7	September 7	.85	31.0
July 7	1.00	48.0			

Daily mean gage height and estimated discharge of Mammoth Creek at Miller House, 1908.

[Elevation, 1,700 feet; drainage area, 37.1 square miles.]

Day.	September.		October.		Day.	September.		October.	
	Gage height.	Discharge.	Gage height.	Discharge.		Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*		*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			0.50	14.4	18	.70	20.7		
2			.50	14.4	19	.90	36.0		
3			.50	14.4	20	.85	31.0		
4			.50	14.4	21	.80	26.8		
5			.50	14.4	22	.70	20.7		
6			.50	14.4	23	.60	16.7		
7			.50	14.4	24	.60	16.7		
8	0.90	36.0	.50	14.4	25	.55	15.4		
9	.80	26.8	.50	14.4	26	.50	14.4		
10	.90	36.0	.40	13.0	27	.50	14.4		
11	.85	31.0	.40	13.0	28		14.9		
12	.70	20.7	.40	13.0	29	.55	15.4		
13	.75	23.4	.40	13.0	30	.50	14.4		
14	.70	20.7							
15	.75	23.4			Mean		22.6		14.0
16	.70	20.7			Mean per sq. mile		.609		.376
17	.75	23.4			Run-off, depth in inches		.52		.18

NOTE.—Creek frozen over after October 13.

Miscellaneous measurements in Mammoth Creek drainage basin, 1908.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		Sq. miles.	*Sec.-ft.*	*Sec.-ft.*
September 6	Mastodon Creek at claim 21 above	6.9	3.9	0.565
September 7	do	6.9	9.1	1.32
July 5	Mastodon Creek at claim 1 above	10.4	7.7	.742
September 7	do	10.4	11.5	1.11
July 5	Independence Creek near mouth	13.2	4.6	.348
September 7	do	13.2	11.9	.902
July 6	Miller Creek near mouth	10.5	5.9	.562
September 7	do	10.5	11.2	1.07

PORCUPINE CREEK.

Porcupine Creek, the left branch of Crooked Creek, rises in the high ridges around Porcupine Dome and flows southeastward through a deep, unsymmetrical valley for about 14 miles to Crooked Creek. Bonanza Creek, a tributary from the right, enters about 4 miles above the mouth.

The following miscellaneous measurements were made in its upper drainage basin in 1908: Porcupine Creek near proposed ditch intake, elevation, about 2,200 feet; discharge, 12.6 second-feet; drainage area,

17.8 square miles; discharge, 0.708 second-foot per square mile. Bonanza Creek at ditch intake, elevation, 2,200 feet; July 4, discharge, 12.4 second-feet; July 6, discharge, 13 second-feet; September 7, discharge, 12.3 second-feet; drainage area, 7.9 square miles; discharge, 1.56, 1.64, and 1.56 second-feet per square mile, respectively.

In 1908 Berry & Lamb constructed along the right side of these creeks a ditch for hydraulicking on Mammoth Creek. This ditch is described in detail on pages 95–96 of this report.

A gaging station was established on Porcupine Creek below Bonanza Creek July 4, 1908. Readings were taken by Mr. Miller, in the employ of Berry & Lamb.

Discharge measurements of Porcupine Creek below Bonanza Creek, 1908.

Date.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*
July 4	1.55	25.0
July 6	1.58	26.0
September 7	1.70	38.8

Daily gage height and estimated discharge of Porcupine Creek below Bonanza Creek, 1908.

[Drainage area, 39.9 square miles.]

Day.	July.		August.		Day.	July.		August.	
	Gage height.	Discharge.	Gage height.	Discharge.		Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*		*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			1.37	16.8	20	1.49	21.3		
2			1.37	16.8	21	1.44	19.2		
3			1.32	16.1	22	1.40	17.8		
4	1.55	24.5	1.30	15.7	23	1.42	18.5		
5	1.53	23.4	1.29	15.6	24	1.50	21.7		
6	1.79	53.5	1.39	15.7	25	1.51	22.3		
7	2.26	147	1.28	15.5	26	1.48	20.8		
8	2.10	115	1.32	16.1	27	1.46	19.9		
9	1.95	85.5	1.48	20.8	28	1.44	19.2		
10	1.85	65.5	1.50	21.7	29	1.44	19.2		
11	1.90	75.5			30	1.42	18.5		
12	1.72	41.8			31	1.40	17.8		
13	1.64	31.5							
14	1.72	41.8			Mean		40.0		17.1
15	1.76	48.1			Mean per square mile		1.00		.429
16	1.72	41.8							
17	1.68	36.3			Run-off, depth in inches		1.04		.16
18	1.61	29.0							
19	1.52	22.8							

BOULDER CREEK.

Boulder Creek rises in the dividing ridge north of the North Fork of Harrison Creek and drains a rather narrow valley between Mammoth and Deadwood creeks. It is about 12 miles long, flows in a northeasterly direction, and empties into Crooked Creek about 4 miles above Central House.

The following discharge measurements were made at the mouth of this stream in 1908: July 1, discharge, 8 second-feet; July 2, 5.8 second-feet; drainage area, 38.8 square miles; discharge per square mile, 0.206 and 0.150 second-foot, respectively.

DEADWOOD CREEK.

Deadwood Creek rises in the ridge to the north of Harrison Creek, drains a precipitous V-shaped area between that stream and Boulder Creek, and unites with Crooked Creek about 4 miles below Central House. It is about 20 miles long. For about 8 miles the stream flows through the narrow part of the area and is very steep. Below Switch Creek, a tributary from the right, the grade lessens and the valley gradually widens until it merges into that of Crooked Creek.

About 35 claims are being worked on this creek, all by the "open-cut" method. The stretch including the lower 3 or 4 miles is being prospected for dredging purposes. A churn drill will probably be put on this part of the ground during the coming season.

The following discharge measurements were made July 1, 1909: Deadwood Creek above Switch Creek, 9.1 second-feet; drainage area, 21.3 square miles; discharge per square mile, 0.427 second-foot. Switch Creek at mouth, 0.72 second-foot; drainage area, 5.8 square miles; discharge per square mile, 0.124 second-foot.

THE RAMPART DISTRICT.

DESCRIPTION OF AREA.

The area originally known as the Rampart district embraces three main drainage areas, as follows: Minook and Troublesome creeks, tributary to Yukon River, and Baker Creek, tributary to the Tanana.

Mining was actively begun in this region in 1896 on Little Minook Creek, which is tributary to Minook Creek from the right about 5 miles from its mouth, and its total gold output since that time exceeds $2,000,000.

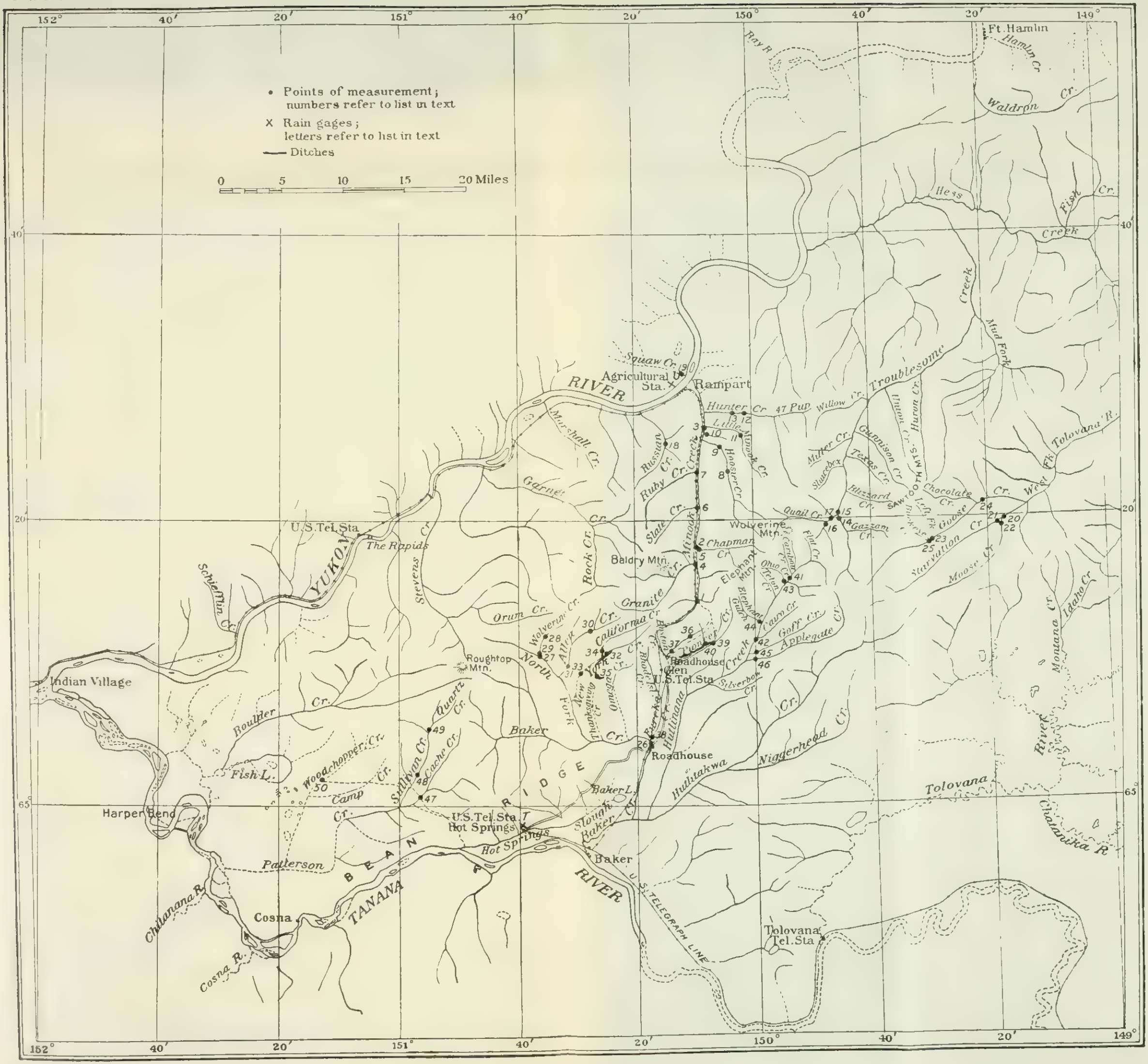
The town of Rampart, situated on the left bank of the Yukon River just below the mouth of Minook Creek, was long the main supply point for the entire region, and from it all the mining outfits and provisions were hauled on sleds in winter and packed on horses in summer. Now, however, the Baker Creek area is by far the largest producer, and since several stores have been opened at Hot Springs, about 6 miles from the Tanana River on the Baker Slough, Rampart has ceased to be the main trading point, and the term "Rampart district" is now understood by some to include only Minook and Troublesome creeks. In this report, however, the original meaning is retained.

The divide between Minook Creek and Baker Creek drainage basins has a general but very irregular east and west direction, with a notable break to the north at the head of Hutlinana Creek. It varies in elevation from 1,000 to 4,000 feet, Wolverine Mountain being the highest point. The northern area is rugged and mountainous, with narrow valleys and precipitous slopes, even down to the mouth of the streams, while the southern area, although rough at the headwaters, broadens out below into alluvial flats in which the streams are sluggish.

Timber sufficient for fuel is found in most of the valleys and lower slopes of the Rampart region. Spruce, birch, and poplar are abundant on the hillsides near Hot Springs and along the Tanana. Minook Creek Valley originally contained timber suitable for mine supports, but of such timber little is left. Timber near the mines, scanty at best, is being destroyed by forest fires which are depleting the supply much more rapidly than the many legitimate uses to which it is being put.

Hot Springs, situated in a country which, except in the immediate vicinity of the mining claims, is practically a wilderness, affords all the luxuries and conveniences which are associated with a modern summer hotel in the States, including shower baths, swimming pools, comfortable rooms with hot and cold water, fresh milk, eggs, and vegetables. The farm of several acres is cultivated by modern methods. An extensive system of hothouses furnishes means of maturing many varieties of fruit and vegetables that could not otherwise be raised, even in the warm ground in the vicinity of the springs.

Transportation facilities in this region are reasonably good. Minook and Troublesome creeks receive their supplies via the Yukon River from Rampart as the distributing point. The Alaska Road Commission has built, up Minook Valley, about 6 miles of road which is very good during the dry season and which, as comparatively little mining is carried on above that point, meets as well as could be expected the needs of this country, where road construction and particularly road maintenance are so expensive. The Baker Creek workings are reached via the Tanana River, with Hot Springs as distributing point. Mr. Frank Manley, who has done so much toward developing that country, constructed during 1906 and 1907 about 30 miles of road between Hot Springs and Thanksgiving and Pioneer creeks. This road was improved during 1908 by the road commission and now affords direct and comfortable access to practically all the Baker Creek mines. A road between Hot Springs and the Patterson Creek mines was also under construction by the road commission during the latter part of the season of 1908. This road will follow the right bank of the Baker Slough to within about one-



MAP SHOWING LOCATION OF GAGING STATIONS IN RAMPART DISTRICT.

half mile of its mouth, where the course turns abruptly to the right and passes over the divide into the Patterson Creek basin. When completed it will afford wagon communication with the Tanana River boats, will make possible the transportation of heavy mining machinery, and will also do away with the present necessity of packing all the supplies to Patterson Creek—a very expensive and tedious method, even under the most favorable conditions.

As in the Fairbanks and Circle districts, much valuable ground is lying idle or being worked at excessive cost because of the lack of water, and some practical means of securing an adequate supply becomes more vitally important each year and presents a problem which should receive the careful consideration of every mine owner.

GAGING STATIONS.

The following list gives the points in the Rampart district at which gages were established or measurements made in 1908. The numbers refer to Plate V.

Gaging stations in Rampart district, 1908.

1. Minook Creek 4½ miles above Chapman Creek.
2. Minook Creek below Chapman Creek.
3. Minook Creek above Little Minook Creek.
4. Granite Creek at road crossing.
5. Chapman Creek at mouth.
6. Slate Creek at mouth.
7. Ruby Creek at mouth.
8. Hoosier Creek above and below pipe intake.
9. Hoosier Creek at claim 11 above.
10. Little Minook Junior Creek at mouth.
11. Little Minook Creek at claim 9 above.
12. Hunter Creek at claim 17 above.
13. Hunter Creek at claim 14 above.
14. Troublesome Creek above Quail Creek.
15. Troublesome Creek below Quail Creek.
16. Quail Creek above South Fork and South Fork at mouth.
17. Quail Creek above Nugget Gulch.
18. Russian Creek 3 miles above mouth.
19. Squaw Creek at mouth.
20. West Fork of Tolovana River near Moose Creek.
21. Starvation Creek at mouth.
22. Moose Creek at mouth.
23. Goose Creek below Buckeye Creek.
24. Goose Creek 4 miles above mouth.
25. Buckeye Creek at mouth.
26. Baker Creek at road crossing.
27. North Fork of Baker Creek below Wolverine Creek.
28. Wolverine Creek 2 miles above mouth.
29. Wolverine Creek at mouth.
30. Allen Creek 5 miles above mouth.
31. Allen Creek at trail crossing.

32. New York Creek at Thanksgiving ditch intake.
33. New York Creek at trail crossing.
34. California Creek at Thanksgiving ditch intake and California Creek branch of Thanksgiving ditch near intake.
35. Thanksgiving ditch near outlet.
36. Eureka Creek at claim 14 above.
37. Eureka Creek at claim 5 above.
38. Eureka Creek at mouth.
39. Pioneer Creek at What Cheer Bar ditch intake.
40. What Cheer Bar ditch near Seattle Creek.
41. Hutlinana Creek below Caribou Creek.
42. Hutlinana Creek below Cairo Creek.
43. Ohio Creek at trail crossing.
44. Elephant Gulch at mouth.
45. Goff Creek near mouth.
46. Applegate Creek 1 mile above mouth.
47. Cache Creek at trail crossing.
48. Sullivan Creek 3 miles above mouth.
49. Quartz Creek near mouth.
50. Woodchopper Creek at trail crossing.

MINOOK CREEK DRAINAGE BASIN.

GENERAL DESCRIPTION.

Minook Creek heads on the northern slope of Eureka Dome, flows northeastward for about 4 miles, and then takes a northerly course through a remarkably straight valley to the Yukon River, which it joins just above Rampart. It is about 25 miles long and drains an area of 198 square miles, the major portion being on the east of the stream. The basin is covered with a light growth of timber which furnishes an ample supply for fuel but very little suitable for milling.

The chief tributaries are Chapman, Hoosier, Little Minook, and Hunter creeks from the east and Granite, Ruby, and Slate creeks from the west. Above Granite Creek the valley is narrow and V-shaped; below that point it broadens out and has perhaps a maximum width of one-half mile. The western slope is precipitous throughout the entire length, while the eastern slope below Chapman Creek is more gradual, with prominent benches. In the upper course the stream is crooked, meandering from one side of the valley to the other; the lower part is comparatively straight.

The summer and winter trails from Rampart to Eureka coincide through the greater part of the distance—to a point about 2 miles above Granite Creek, where the summer trail crosses the creek and passes on to the divide between Eureka and Pioneer creeks. The winter trail keeps to the left of Minook Creek, crosses the divide to the west of Eureka Dome, and passes down the right limit of Boston Creek. The trail is very difficult to travel, owing to the large quantity of ground ice along its left bank, which keeps it saturated even during the driest part of the summer season.

"Just below the mouth of Slate Creek the Minook spreads into a number of branches in a wide gravel flat. This flat, which is typical of many Alaskan streams, is probably due to a change in the grade of the creek. The stream here is unable to carry the gravels of the swifter water above, and so spreads them upon the flat. Here are found the so-called 'winter glaciers,' some of which last through the short summers. In 1904 a quarter or half acre of 'winter glacier' still remained when the September frosts occurred. This ice owes its origin to the fact that, as the water freezes in the fall, the channel is greatly narrowed. The resulting hydrostatic pressure cracks the ice and the water overflows and freezes. This process is repeated until considerable thickness of ice is accumulated."[a]

MINOOK CREEK ABOVE LITTLE MINOOK CREEK.

A board gage was erected May 25, 1908, by M. E. Koonce on Minook Creek just above Little Minook Creek. This gage was read by the miners of Hoosier and Little Minook creeks on their way to and from Rampart.

Discharge measurements of Minook Creek above Little Minook Creek, 1908.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*		*Feet.*	*Sec.-feet.*
August 9	1.58	31.3	September 12	1.91	56.9
August 16	1.50	30.4	September 14	1.86	49.9
September 5	2.50	110.0	September 15	1.85	50.1
September 7	2.25	82.5	September 19	2.25	81.9
September 10	2.15	70.9			

Daily gage height and estimated discharge of Minook Creek above Little Minook Creek, 1908.

[Elevation, 425 feet; drainage area, 130 square miles.]

Day.	May.	June.		July.		August.		September.	
	Gage height.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1		3.6		2.2	77	1.60	33	1.70	38
2		3.6			73		34		68
3					69		36		98
4					65	1.70	38	2.65	128
5					58	1.70	38	2.50	110
6				1.9	51		37	2.35	92
7		2.9	160		77		35	2.25	82
8			159	2.4	98		34	2.29	86
9		2.8	147	2.5	110	1.60	33	2.20	77
10		2.5	110	2.2	77	1.57	32	2.15	72
11			119		74	1.55	31		61
12			128		70		31	1.90	51
13			137		67		31		50
14			146		63	1.55	31	1.85	48
15			155		60	1.50	30	1.85	48

[a] Hess, F. L., The Rampart placers: Bull. U. S. Geol. Survey No. 337, 1908, pp. 67–68.

Daily gage height and estimated discharge of Minook Creek above Little Minook Creek, 1908—Continued.

Date.	May.	June.		July.		August.		September.	
	Gage height.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
16	.....	.....	164	.....	56	1.50	31	.....	59
17	.....	.....	173	.....	53	.....	32	.....	70
18	.....	.....	182	.....	49	.....	33	2.25	82
19	.....	.....	191	.....	46	.....	34	.....	72
20	.....	3.20	200	.....	42	.....	35	.....	62
21	.....	2.92	163	1.70	38	1.65	35	.....	51
22	.....	.....	147	.....	38	.....	35	1.80	44
23	.....	.....	131	.....	37	.....	34	.....	.....
24	.....	2.55	116	.....	36	1.60	33	.....	.....
25	4.70	.....	103	.....	36	1.65	35	.....	.....
26	4.10	.....	90	.....	35	1.60	33	.....	.....
27	4.91	2.20	77	1.65	35	.....	34	.....	.....
28	.....	.....	77	.....	35	.....	35	.....	.....
29	.....	.....	77	.....	35	.....	36	.....	.....
30	4.15	2.20	77	.....	34	.....	37	.....	.....
31	4.25	.....	.....	.....	34	.....	38	.....	.....
Mean	.....	.....	134	.....	56.0	.....	34.0	.....	70.4
Mean per square mile	.....	.....	1.03	.....	.431	.....	.262	.....	.542
Run-off, depth in inches	.....	.....	.92	.....	.50	.....	.30	.....	.44

GRANITE CREEK.

Granite Creek rises opposite Allen Creek in the Baker-Minook divide and flows in a northeast direction, entering Minook Creek about 16 miles from the Yukon. It is about 8 miles long and is the third largest tributary of Minook Creek. The lower valley is V-shaped, with steep rocky slopes, and the bed is of heavy bowlders intermixed with gravel. The upper valley was not visited.

The following measurement was made near the mouth August 8, 1908: Discharge, 5.7 second-feet; drainage area, 26.9 square miles; discharge, 0.212 second-foot per square mile.

CHAPMAN CREEK.

Chapman Creek enters Minook Creek from the east about 1 mile below Granite Creek. It heads on the north slope of Elephant Mountain and is about 5 miles long. Considerable work has been done on the creek and favorable prospects have been found, but no actual mining has been carried on.

The following measurement was made August 8, 1908, near the mouth: Discharge, 2.9 second-feet; drainage area, 14.8 square miles; discharge, 0.196 second-foot per square mile.

SLATE CREEK.

Slate Creek is tributary to Minook Creek about 12 miles from the Yukon. It heads on the north slope of Baldy Mountain and has a length of 5 miles, with an average grade of nearly 350 feet per mile. The valley is V-shaped near the mouth and unsymmetrical toward the headwaters of the stream, with rugged slopes well covered with timber. This creek has been worked since 1902, and good values are said to have been found.

The following measurement was made near the mouth August 8, 1908: Discharge, 2.2 second-feet; drainage area, 7.9 square miles; discharge, 0.278 second-foot per square mile.

RUBY CREEK.

Ruby Creek, the first western tributary of importance, enters Minook Creek about 8 miles from the Yukon and 3 miles above the mouth of Hoosier Creek. Its course is northeastward, parallel to that of Slate Creek. It is about 8 miles long.

The valley is sharp cut and unsymmetrical. The right side has several small tributaries, while the left is broken only by mere rills.

The producing claims are all within 1½ miles of the mouth. Prospecting above that point has been hampered by live water in the gravels.

On August 8, 1908, a measurement was made as follows: Discharge, 1.7 second-feet; drainage area, 10.6 square miles; discharge, 0.160 second-foot per square mile.

HOOSIER CREEK.

Hoosier Creek rises in the high divide at the head of Chapman Creek and flows northwestward, emptying into Minook Creek from the right about 5 miles above its mouth. Practically the only mining on this creek in 1908 was at claim 14 above where a hydraulic elevator was in operation during a portion of the season. A gaging station was established on claim 11 above, August 16, and readings taken by M. E. Koonce.

Discharge measurements of Hoosier Creek at claim 11 above, 1908.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
August 16	0.35	4.7	September 9	0.57	14.5
September 5	.65	20.6	September 14	.43	7.2

Daily gage height and estimated discharge of Hoosier Creek at claim 11 above, 1908.

[Elevation, 600 feet; drainage area, 25.7 square miles.]

Day.	August.		September.		Day.	August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.		Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*		*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			0.40	8.0	20	0.35	4.7	0.45	8.0
2				25.0	21		4.7	.35	4.7
3			.85	42.0	22		4.7		
4			.70	25.4	23		4.7		
5			.70	25.4	24		4.7		
6			.55	13.0	25		4.7		
7			.65	20.6	26		4.7		
8			.55	13.0	27		4.7		
9				11.6	28		4.7		
10			.50	10.2	29		4.7		
11				9.5	30		4.7		
12				9.0	31	.35	4.7		
13				8.5					
14			.45	8.0	Mean		4.70		13.6
15			.45	8.0	Mean per square mile		.183		.529
16	0.35	4.7	.45	8.0	Run-off, depth in inches		.10		.41
17	.35	4.7	.43	7.7					
18	.35	4.7	.50	10.2					
19		4.7		9.1					

LITTLE MINOOK JUNIOR CREEK.

Little Minook Junior Creek is a small tributary of Minook Creek and drains a small area between the mouths of Little Minook and Hoosier creeks.

It is about 2½ miles long. The lower valley has a heavy grade and is sharply V-shaped. The upper valley has more gentle slopes and a lower stream gradient.

But little mining work was accomplished during the summer of 1908, owing to the lack of water, although some very rich ground was said to have been found. The stream probably seldom furnishes a sluice head of water except during the spring run-off.

A measurement was made near the mouth on September 5, 1908: Discharge, 0.32 second-foot; drainage area, 1.3 square miles; discharge, 0.246 second-foot per square mile.

LITTLE MINOOK CREEK.

Little Minook Creek is tributary to Minook Creek about 5 miles from the Yukon. Its drainage basin lies between Hunter and Hoosier creeks and is entirely surrounded by them. The course of the stream is parallel to that of Hunter Creek, with the same pronounced bend to the left about 3 miles from its mouth. The valley is sharply V-shaped with precipitous slopes, sparsely covered with small timber. This stream has been the largest producer of the Minook basin, but it has been worked in a rather unsystematic manner on account of the many different owners. Underground water also has caused considerable trouble, making it necessary to abandon some ground shown

to be rich. No pay has been found above claim 9 above. A favorite method of removing the overburden of muck and gravel during the open season is by means of automatic dams (Pl. VII, *B*). A gaging station was established on this stream at claim 9 above on June 21, 1908, and readings were taken by Messers. Nelson, Cummings, and Larson.

Discharge measurements of Little Minook Creek at claim 9 above, 1908.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-feet.*		*Feet.*	*Sec.-feet.*
August 10	0.79	0.75	September 7	0.98	2.5
August 15	.79	.67	September 15	.91	1.3
September 4	1.17	6.8			

Daily gage height and estimated discharge of Little Minook Creek at claim 9 above, 1908.

[Elevation, 900 feet; drainage area, 5.9 square miles.]

Day.	June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			0.92	1.60	0.75	0.62	1.08	4.2
2			.92	1.60	.83	.87	1.17	6.8
3			.92	1.60		.84	1.21	10.1
4			.83	.87		.82	1.17	6.8
5			.83	.87		.80		5.3
6			.92	1.60		.78		3.8
7			1.08	4.20		.76	.98	2.3
8			1.50	26.40		.74		2.2
9			1.42	20.50		.72		2.1
10			1.33	14.60	.79	.70		2.0
11			1.33	14.60		.70		1.9
12				10.30		.70		1.8
13				6.00		.70		1.7
14			.92	1.60		.70		1.6
15			.83	.87	.79	.70	.91	1.4
16			.83	.87		.76		
17			.75	.62		.82		
18			.75	.62	.83	.87		
19				.62		.87		
20				.62		.87		
21	1.17	6.8		.62		.87		
22	1.08	4.2		.62		.87		
23	1.00	2.6		.62		.87		
24	.92	1.6		.62		.87		
25	.92	1.6		.62		.87		
26	.92	1.6		.62		.87		
27	.92	1.6		.62		.87		
28	.92	1.6		.62		.87		
29	.92	1.6		.62		.87		
30	.92	1.6		.62		.87		
31			.75	.62	.83	.87		
Mean		2.48		3.78		.800		3.60
Mean per square mile		.420		.641		.136		.610
Run-off, depth in inches		.16		.79		.16		.34

HUNTER CREEK.

Hunter Creek, the largest tributary of Minook Creek, enters it from the right about 3 miles from its mouth. It flows northward to its junction with 47 Pup, where it makes a right-angle turn to the west, entering Minook Creek about 6 miles farther on. It is a crooked stream about 12 miles long, and has a narrow V-shaped valley and rough precipitous slopes. The lower part of the valley on the right side is marked by a very pronounced bench which so far has furnished the chief gold-bearing gravels. Hunter Creek has a particularly heavy growth of timber, much of which would be suitable for saw logs.

Two hydraulic plants were in operation on this creek during 1908—one on Discovery claim and one on claim 17 above. A gaging station was established on this stream at claim 17 above, August 11, 1908, and regular readings were taken by S. M. Wheeler.

Discharge measurements of Hunter Creek at claim 17 above, 1908.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
August 11	0.50	4.5	September 10	0.79	12.7
September 6	.90	17.9	September 16	.65	8.4

Daily gage height and estimated discharge of Hunter Creek at claim 17 above, 1908.

[Elevation 600 feet; drainage area, 33.4 square miles.]

Day.	August.		September.		Date.	August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.		Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*		*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			0.60	6.6	21	0.55	5.5		
2			.75	11.4	22	.50	4.5		
3			1.05	25.1	23	.45	3.7		
4			1.10	27.7	24	.50	4.5		
5			1.00	22.6	25	.50	4.5		
6			.90	17.9	26	.50	4.5		
7			.85	15.6	27	.50	4.5		
8			.85	15.6	28	.50	4.5		
9				14.1	29	.50	4.5		
10			.79	12.6	30	.50	4.5		
					31	.55	5.5		
11	0.50	4.5		11.1					
12	.55	5.5	.70	9.6	Mean		4.60		15.8
13	.50	4.5			Mean per square mile		.138		.473
14	.50	4.5			Run-off, depth in inches		.11		.14
15	.50	4.5							
16	.50	4.5							
17	.50	4.5							
18	.50	4.5							
19	.50	4.5							
20	.50	4.5							

MISCELLANEOUS MEASUREMENTS.

The following measurements, not previously listed, were made in the Minook Creek drainage basin in 1908.

Miscellaneous measurements in Minook Creek drainage basin, 1908.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		Sq. miles.	*Sec.-ft.*	*Sec.-ft.*
August 8	Minook Creek 4½ miles above Chapman Creek	9.2	2.9	0.315
Do	Minook Creek below Chapman Creek	58.3	7.1	.122
August 10	Hoosier Creek above pipe intake	21.2	4.8	.226
September 9	do	21.2	11.1	.523
Do	Hoosier Creek below pipe intake		1.2	
August 10	Hunter Creek at 14 above	33.4	2.3	.069
September 5	Little Minook Junior Creek at mouth	1.3	.32	.246

TROUBLESOME CREEK DRAINAGE BASIN.

GENERAL DESCRIPTION.

Troublesome Creek rises southeast of Wolverine Mountain, between the headwaters of Hutlinana Creek and the West Fork of the Tolovana River, and flows northeastward for about 40 miles, entering Hess Creek 10 miles from the Yukon River.

No study of this creek was made below the mouth of Quail Creek, but it is said to follow a winding course, meandering from one side of the valley to the other through soft mucky soil, abounding with "niggerheads" and a thick growth of small trees which make travel slow and tedious. It also has steep, high slopes which make it very difficult of approach.

The main and tributary valleys at the head are almost canyon-like in appearance, being shut in by rocky, barren ridges which are high and precipitous.

Troublesome Creek seems to be the only one near enough to the Rampart mines with sufficient run-off and gradient to be worthy of consideration as a possible water supply for the development of hydro-electric power to be transmitted to that region. The approximate average grade of the stream below the mouth of Quail Creek is 45 feet per mile, ranging from 150 feet per mile at the upper limit to 18 feet per mile at the mouth.

About 7 miles from the head Troublesome Creek receives Quail Creek, its first important tributary. Quail Creek heads opposite Hoosier Creek and flows eastward, draining the north slope of Wolverine Mountain. It is about 5 miles long and drains an area of 20.6 square miles. The south slope of its basin is rocky and barren, rising precipitously to the summit of Wolverine Mountain. On the north the valley has a very gentle approach and is covered with a

heavy growth of wild grass which furnishes excellent forage for pack animals. The stream is lined with a dense growth of willows in the upper portion, and near the mouth is a growth of spruce suitable for cabin and fuel purposes. A trail from Rampart to the mouth of Quail Creek, a distance of about 20 miles, follows up the right side of Little Minook Creek, crosses the divide, and passes diagonally down the long, gentle slope on the left side of Quail Creek.

Considerable work was being done on the creek during the summer of 1908, and gold values were said to have been found in the gravels. The work thus far carried on has been prospecting rather than actual mining.

The South Fork joins Quail Creek about a mile above Troublesome Creek and is its largest tributary.

TROUBLESOME CREEK BELOW QUAIL CREEK.

A gaging station was established on Troublesome Creek below the mouth of Quail Creek, August 12, 1908, and regular readings were taken by C. F. W. Cassidy.

Discharge measurements of Troublesome Creek below Quail Creek, 1908.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*		*Feet.*	*Sec.-ft.*
August 12	0.75	7.2	September 3	1.20	35.7
August 14	.73	6.2	September 4	1.30	50.4
September 2	1.07	25.4			

Daily gage height and estimated discharge of Troublesome Creek below Quail Creek, 1908.

[Elevation 1,750 feet; drainage area 43.2 square miles.]

Day.	August.		September.		Day.	August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.		Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*		*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			0.86	11.2	20	0.79	8.3	.....	10.3
2			1.04	23.2	21	.78	8.0	.....	10.0
3			1.2	38.0	22	.78	8.0	.....	9.8
4			1.3	48.0	23	.75	7.0	0.82	9.6
5			.....	46.0	24	.73	6.4	.68	5.2
6			.....	43.0	25	.75	7.0	.60	4.0
7			.....	41.0	26	.78	8.0	.....	.....
8			.....	37.5	27	.75	7.0	.....	.....
9			.....	34.6	28	.....	8.0	.....	.....
10			.....	32.0	29	.82	9.4	.....	.....
11			1.11	29.2	30	.80	8.6	.....	.....
12	0.75	7.0	1.1	28.3	31	.78	8.0	.....	.....
13	.....	6.7	1.03	22.4					
14	.73	6.4	.90	13.4	Mean	.....	7.48	.....	22.2
15	.....	6.3	.....	13.0	Mean per square mile	.....	.173	.....	.518
16	.72	6.2	.....	12.6	Run-off, depth in inches	.....	.13	.....	.48
17	.75	7.0	.....	12.2					
18	.78	8.0	.....	10.9					
19	.79	8.3	.....	10.6					

MISCELLANEOUS MEASUREMENTS.

The following measurements were made to determine the proportional discharge of Troublesome Creek and its tributaries:

Miscellaneous measurements in Troublesome Creek drainage basin, 1908.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		Sq. miles.	*Sec.-ft.*	*Sec.-ft.*
August 12	Troublesome Creek above Quail Creek	21.4	2.5	0.117
Do	Quail Creek above South Fork	13.3	2.8	.210
Do	Quail Creek above Nugget Gulch	17.6	4.3	.244
Do	South Fork of Quail Creek at mouth	3.7	1.4	.378

MINOR YUKON RIVER DRAINAGE.

RUSSIAN CREEK.

Russian Creek enters Yukon River from the south about 4 miles below Rampart. It has an unsymmetrical valley with steep slopes and a rather broad bottom land, thickly covered with small trees. It is about 8 miles long and flows in a general northerly direction.

A measurement was made about 3 miles above the mouth on September 19, 1908, as follows: Discharge, 1.9 second-feet; drainage area, 9.9 square miles; discharge, 0.192 second-foot per square mile.

SQUAW CREEK.

Squaw Creek enters Yukon River just above Rampart, directly opposite Minook Creek. The creek was not seen above the mouth, but the upper valley is said to have a valuable growth of timber, and plans were being made to install a portable sawmill on the creek during the winter of 1908–9. Considerable winter prospecting has been done, but no values are reported. A measurement was made September 11, 1908, at the mouth, which gave a discharge of 27.7 second-feet.

WEST FORK OF TOLOVANA RIVER DRAINAGE BASIN.

DESCRIPTION.

The West Fork of Tolovana River is formed by three main arteries—Goose, Starvation, and Moose creeks—which flow northeastward in generally parallel courses the greater portion of their length. They are separated by bench-like divides which rise 600 to 800 feet above the valley bottoms.

Goose Creek is the largest of the three and drains the highest ground. Sawtooth Mountain, rising high above it on the north, contributes the greater part of the run-off. The valley has an average width of perhaps one-fourth mile and is rather difficult to travel,

having an extra thickness of the prevalent moss and containing many "niggerheads" in a bed of muck and water. The bottom land is dotted with clumps of spruce and birch, but the timber generally is small. The creek crosses from side to side of the valley, and its gravelly bed contains large bowlders. The right slope is steep and makes a sharp angle with the bottom land and is unbroken by any noticeable water courses below Buckeye Creek. The left bank is marked by numerous feeders with deep-cut valleys extending back for several miles.

Buckeye Creek is tributary to Goose Creek from the left about 10 miles from the mouth. It has shown sufficient gold to warrant careful prospecting. The creek, however, probably never furnishes sufficient water for anything more than the washing of spring dumps.

Starvation and Moose creeks were visited only at the mouth, but as seen from a distance the lower valleys appeared to have the same general characteristics as those of Goose Creek.

MEASUREMENTS.

Miscellaneous measurements in West Fork of Tolovana River drainage basin, 1908.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		Sq. miles.	*Sec.-ft.*	*Sec.-ft.*
August 13	West Fork of Tolovana River near Moose Creek	43.8	4.0	0.091
Do	Starvation Creek at mouth	23.8	2.2	.092
Do	Moose Creek at mouth	19.8	1.9	.096
Do	Goose Creek 4 miles above mouth	41.0	3.2	.078
August 14	Goose Creek below Buckeye Creek	20.8	1.6	.077
Do	Buckeye Creek at mouth	10.6	.20	.019

BAKER CREEK DRAINAGE BASIN.

GENERAL DESCRIPTION.

Baker Creek and its tributaries drain a roughly fan-shaped area 542 square miles in extent. The greatest width of this basin from east to west is 37 miles, and its greatest width from north to south, 21 miles.

The name Baker Creek is applied to the extreme western fork. It heads near Sullivan Creek on the south slope of Roughtop Mountain and flows eastward for about 17 miles; it then makes a right-angle turn to the south around the north end of Bean Ridge which it follows closely for about 4 miles below the turn, where it crosses the flat and receives its two largest tributaries, Hutlinana and Hutlitakwa creeks, which drain over half the entire area. It is about 28 miles long and enters the Tanana 70 miles from the Yukon.

The system of main and tributary streams is very unsymmetrical, about 88 per cent of the area lying on the left side. South of the creek the country rises abruptly to the summit of Bean Ridge and

furnishes no tributaries of importance. On the north the valley spreads out into a broad, alluvial flat with a very gradual slope until near the head of the tributaries, where it rises abruptly to the summit of the divide.

No values have yet been found on the main creek, the chief producing creeks being Thanksgiving, Glenn, Eureka, and Pioneer.

The basin as a whole is favored with an abundant and diversified growth of timber. In the upper drainage this growth is small, but has furnished sufficient supply for fuel and cabins; on the flats, particularly in the lower valley of the Hutlinana, there is considerable spruce suitable for milling. Several sawmills have been in operation during the past two or three winters, but their output has been mainly flume lumber. On the slope near Hot Springs there is a heavy growth of birch and poplar.

Baker Creek has such a low gradient that its water can never be conveyed to any of the present mines by a gravity system, but as a supply for pumping it is ample, and it is so situated that it is worth consideration for that purpose.

BAKER CREEK AT ROAD CROSSING.

A gaging station was established on Baker Creek just above the road crossing, and below Eureka Creek. The gage is referred to a stake driven in the left bank about 15 feet from the gage, the top of which is 6.33 feet above the gage datum. Readings were taken twice a day by Charles H. Dickson, but as no measurements were made during the higher stages in September, no daily discharges can be computed.

Discharge measurements of Baker Creek at road crossing, 1908.

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
August 6	1.00	41.2
August 21	1.03	44.5
August 27	.98	42.8

ALLEN CREEK.

Allen Creek, which enters the North Fork of Baker Creek about $2\frac{1}{2}$ miles above the mouth of New York Creek, is about 8 miles long. It flows southwestward in a winding course between deep-cut, mucky banks, splitting at many places into several channels, causing numerous island-like formations. The banks are lined with an almost impenetrable growth of willows. The left slope is rocky and barren and in some places rises almost vertically from 600 to 800 feet above the stream. The right side of the valley, which furnishes the greater

part of the run-off, slopes gradually to the summit, which is capped by rocky cliffs. Allen Creek has been considered as a possible auxiliary water supply for the Thanksgiving Creek mines.

The following measurements were made August 22, 1908, at trail crossing: One mile above mouth, discharge, 4.9 second-feet; drainage area, 15.3 square miles; discharge, 0.320 second-foot per square mile. Five miles above mouth, discharge, 2.7 second-feet; drainage area, 5.9 square miles; discharge, 0.457 second-foot per square mile.

NEW YORK CREEK AT THANKSGIVING DITCH INTAKE.

New York Creek rises in a rather low saddle opposite the headwaters of Minook Creek and flows southwestward about 10 miles to North Fork of Baker Creek. The upper valley of this creek is narrow, V-shaped, and precipitous.

June 6, 1908, a gage was installed on New York Creek above the intake to Thanksgiving ditch, and daily readings were taken by employees of Frank G. Manley.

Discharge measurements of New York Creek at Thanksgiving ditch intake, 1908.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*
June 6	C. C. Covert	0.40	5.3
June 8	do	.34	4.5
July 7	A. V. Thorns	.05	.71
August 7	C. E. Ellsworth	.09	1.1
August 18	do	.12	1.4

Daily gage height and estimated discharge of New York Creek at Thanksgiving ditch intake, 1908.

[Elevation, 800 feet; drainage area, 4.7 square miles.]

Day.	June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			0.05	0.7			0.40	5.4
2			.05	.7			.35	4.5
3			.10	1.2			.50	7.2
4			.05	.7			.35	4.5
5			.05	.7			.30	3.7
6	0.40	5.4	.05	.7				3.4
7	.35	4.5	.05	.7			.25	3.0
8	.55	8.2	.05	.7	0.10	1.2	.35	4.5
9	.30	3.7	.05	.7	.05	.7	.30	3.7
10	.25	3.0	.15	1.7	.05	.7	.25	3.0
11	.25	3.0	.10	1.2		.7	.20	2.3
12	.25	3.0	.05	.7	.05	.7	.20	2.3
13	.20	2.3	.05	.7		.7	.20	2.3
14	.30	3.7	.05	.7	.05	.7	.20	2.3
15	.40	5.4			.05	.7	.25	3.0
16	.30	3.7			.05	.7	.20	2.3
17	.25	3.0			.05	.7	.25	3.0
18	.25	3.0				1.4	.55	8.2
19	.25	3.0			.25	3.0	.50	7.2
20	.40	5.4			.20	2.3	.45	6.3
21	.30	3.7			.15	1.7		
22	.25	3.0			.15	1.7		
23	.20	2.3			.10	1.2		
24	.20	2.3			.10	1.2		
25	.15	1.7				1.4		

Daily gage height and estimated discharge of New York Creek at Thanksgiving ditch intake, 1908—Continued.

Day	June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
26	.10	1.2	.....	.....	.15	1.7	.....	.....
27	.10	1.2	.....	.....	.10	1.2	.....	.....
28	.10	1.2	.....	.....	.10	1.2	.....	.....
29	.10	1.2	.....	.....	.10	1.2	.....	.....
30	.05	.7	.....	.....	.10	1.2	.....	.....
31	.....	.....	.....	.....	.....	3.0	.....	.....
Mean	.....	3.15	.....	.843	.....	1.29	.....	4.10
Mean per square mile	.....	.670	.....	.179	.....	.275	.....	.873
Run-off, depth in inches	.....	.62	.....	.09	.....	.25	.....	.65

CALIFORNIA CREEK AT THANKSGIVING DITCH INTAKE.

California Creek enters New York Creek from the right about 5 miles from its source.

August 7, 1908, a gage was installed on California Creek above the intake to Thanksgiving ditch and daily readings were taken by employees of Frank G. Manley.

Discharge measurements of California Creek at Thanksgiving ditch intake, 1908.

Date.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*
August 1	1.00	2.4
August 18	1.03	2.9

Daily gage height and estimated discharge of California Creek at Thanksgiving ditch intake, 1908.

[Elevation, 825 feet; drainage area, 6.7 square miles.]

Day.	August.		September.		Day.	August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.		Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*		*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1	.....	.....	1.10	4.2	21	1.00	2.4	.....	.....
2	.....	.....	1.15	5.2	22	1.00	2.4	.....	.....
3	.....	.....	1.25	7.5	23	1.00	2.4	.....	.....
4	.....	.....	1.20	6.3	24	1.00	2.4	.....	.....
5	.....	.....	1.15	5.2	25	.....	2.4	.....	.....
6	.....	.....	.....	4.7	26	1.00	2.4	.....	.....
7	.....	.....	1.10	4.2	27	1.00	2.4	.....	.....
8	1.00	2.4	1.15	5.2	28	1.00	2.4	.....	.....
9	1.00	2.4	1.10	4.2	29	1.00	2.4	.....	.....
10	1.00	2.4	1.05	3.2	30	1.00	2.4	.....	.....
11	.....	2.4	1.10	4.2	31	.....	.....	.....	.....
12	1.00	2.4	1.05	3.2					
13	.....	2.4	1.05	3.2	Mean	.....	2.45	.....	5.07
14	1.00	2.4	1.10	4.2	Mean per square mile	.....	.366	.....	.757
15	1.00	2.4	1.10	4.2	Run-off, depth in inches	.....	.31	.....	.56
16	1.00	2.4	1.05	3.2					
17	1.00	2.4	1.11	4.4					
18	1.03	2.9	1.30	8.7					
19	1.05	3.2	1.30	8.7					
20	1.00	2.4	1.25	7.5					

THANKSGIVING DITCH NEAR OUTLET.

Thanksgiving ditch taps New York and California creeks a short distance above their confluence. It is about 4 miles long and supplies water for use on Thanksgiving Creek, a small tributary of Baker Creek and one of the richest in the Rampart region. The chief workings so far have been near the head of the creek. Prospecting with a churn drill has been carried on below the present workings and also between Thanksgiving and Omega creeks.

During the early part of the season of 1908 much money was spent in constructing bed-rock flumes, installing machinery, and breaking the ground preparatory to stripping, but owing to the exceptionally low water the work was much curtailed.

A steam scraper for use in removing tailings from the sluice boxes was in operation on this creek during part of the season. It was of the bottomless type, with a capacity of 2 cubic yards. A 35-horsepower boiler and a 3-drum hoist, operated by one man, moved 150 cubic yards of dirt an average distance of 150 feet on 1 cord of wood.

A gage was established on this ditch June 6, 1908, about one-fourth mile above the outlet.

Discharge measurements of Thanksgiving ditch near outlet, 1908.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*
June 6	C. C. Covert	1.20	11.2
June 8	do	1.20	10.7
July 7	A. V. Thorns	.60	2.9
August 7	C. E. Ellsworth	.60	2.1
August 18	do	.68	2.7
August 29	do	.60	1.8

Daily gage height and estimated discharge of Thanksgiving ditch near outlet, 1908.

Day.	June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			0.65	2.4			0.90	5.3
2			.60	2.1			.95	6.1
3			.75	3.3			1.20	10.9
4			.70	2.8			1.10	8.9
5			.60	2.1			1.00	7.0
6	1.20	10.9	.60	2.1				6.2
7	1.05	7.9	.60	2.1			.90	5.3
8	1.20	10.9	.65	2.4	0.60	2.1	1.05	7.9
9	1.10	8.9	.60	2.1	.55	1.8	.95	6.1
10	1.05	7.9	.70	2.8	.55	1.8	.90	5.3
11	.95	6.1	.65	2.4		1.7	.80	3.9
12	.95	6.1	.65	2.4	.50	1.6	.75	3.3
13	.90	5.3	.60	2.1		1.6	.75	3.3
14	1.10	8.9	.60	2.1	.50	1.6	.80	3.9
15	1.25	12.0			.50	1.6	.85	4.5

Daily gage height and estimated discharge of Thanksgiving ditch near outlet, 1908—Cont'd.

Day.	June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
16	1.10	8.9			0.50	1.6	0.80	3.9
17	1.05	7.9			.55	1.8	.85	4.5
18	1.10	8.9				2.8	1.25	12.0
19	1.00	7.0			.80	3.9	1.20	10.9
20	1.10	8.9			.70	2.8	1.15	9.9
21	1.25	12.0			.70	2.8		
22	1.00	7.0			.70	2.8		
23	.90	5.3			.65	2.4		
24	.80	3.9			.65	2.4		
25	.70	2.8				2.4		
26	.70	2.8			.65	2.4		
27	.70	2.8			.60	2.1		
28	.70	2.8			.60	2.1		
29	.70	2.8			.60	2.1		
30	.65	2.4			.60	2.1		
31						3.7		
Mean		6.84		2.37		2.25		6.46

CALIFORNIA CREEK BRANCH OF THANKSGIVING DITCH NEAR INTAKE.

June 6, 1908, a gage was placed in the California Creek branch a short distance below the intake, and was read by employees of Frank G. Manley.

Discharge measurements of California branch of Thanksgiving ditch near intake, 1908.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*
June 6	C. C. Covert	0.85	6.0
June 8	do	1.02	7.9
July 7	A. V. Thorns	.65	2.1
August 7	C. E. Ellsworth	.64	2.0
August 18	do	.72	2.5

Daily gage height and estimated discharge of California branch of Thanksgiving ditch near intake, 1908.

Day.	June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			0.65	2.1			0.80	3.6
2			.60	1.8			.90	5.3
3			.70	2.5			.85	4.4
4			.65	2.1			1.00	7.9
5			.65	2.1			.90	5.3
6	0.85	4.4	.65	2.1			.85	4.4
7	.80	3.6	.65	2.1				4.4
8	1.00	7.9	.60	1.8	0.65	2.1	.85	4.4
9	.75	3.0	.65	2.1	.65	2.1	.85	4.4
10	.90	5.3	.70	2.5	.65	2.1	.80	3.6

Daily gage height and estimated discharge of California branch of Thanksgiving ditch near intake, 1908—Continued.

Day.	June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
11	0.80	3.6	0.65	2.1	.....	2.1	0.80	3.6
12	.85	4.4	.65	2.1	0.65	2.1	.75	3.0
13	.80	3.6	.65	2.1	.....	2.1	.80	3.6
14	.90	5.3	.65	2.1	.65	2.1	.80	3.6
15	.95	6.5	.....	.....	.65	2.1	.75	3.0
16	.85	4.4	.....	.....	.65	2.1	.80	3.6
17	.85	4.4	.....	.....	.65	2.1	1.00	7.9
18	.85	4.4	.....	.....	.72	2.7	1.00	7.9
19	.80	3.6	.....	.....	.75	3.0	.75	3.0
20	1.30	17.0	.....	.....	.70	2.5	.95	6.5
21	1.00	7.9	.....	.....	.70	2.5	.....	.....
22	.90	5.3	.....	.....	.70	2.5	.....	.....
23	.80	3.6	.....	.....	.65	2.1	.....	.....
24	.80	3.6	.....	.....	.65	2.1	.....	.....
25	.75	3.0	.....	.....	.....	2.1	.....	.....
26	.70	2.5	.....	.....	.65	2.1	.....	.....
27	.70	2.5	.....	.....	.65	2.1	.....	.....
28	.70	2.5	.....	.....	.65	2.1	.....	.....
29	.70	2.5	.....	.....	.65	2.1	.....	.....
30	.65	2.1	.....	.....	.65	2.1	.....	.....
31	.....	.....	.....	.....	.....	2.1	.....	.....
Mean	.....	4.68	.....	2.08	.....	2.20	.....	4.67

EUREKA CREEK.

Eureka Creek rises in the Minook-Baker divide just east of Eureka Dome, flows southwestward for about 5 miles, then takes a more southerly course and unites with Baker Creek at the point where that creek makes its decided turn to the south. The total length of Eureka Creek is about 12 miles. It receives Boston Creek about 5 miles below its head.

Above Boston Creek the valley resembles that of Pioneer Creek. The south side rises abruptly about 600 feet above the stream and furnishes no tributaries, while the north slope is gentle and is cut by several small streams. Below Boston Creek the valley rapidly broadens into Baker Flats, which are covered with a dense growth of willows intermixed with some good-sized spruce and which the stream crosses in a meandering and sluggish manner through a deep-cut, mucky channel.

The main diggings are near the junction of Boston Creek, although placer-gold values have been found at several points above.

Miscellaneous measurements of Eureka Creek, 1908.

Date.	Locality.	Drainage area.	Discharge.	Discharge per square mile.
		Sq. miles.	*Sec.-ft.*	*Sec.-ft.*
August 21	Claim 14 above	2.8	0.77	0.275
Do	Claim 5 above	5.8	1.3	.224
August 6	Mouth	37.7	4.8	.127

PIONEER CREEK.

Pioneer Creek heads in the south slope of Elephant Mountain and flows southwestward. It is about 11 miles long and, for about 5 miles of its course, parallels Eureka Creek, to which it is a tributary, some 7 miles from the head.

On the south side, which the creek closely follows, the valley rises almost precipitously about 800 feet above the bed of the stream and is broken only by small gulches. The north side, in contrast, exhibits a very gentle slope marked by a prominent bench which is cut at right angles to Pioneer Creek by several small tributaries of similar appearance. There is very little timber in the valley, the supply being barely sufficient for fuel. Most of the diggings are on the north slope. What Cheer Bar, Seattle Bar, Doric Creek, Boothby Creek, and Joe Bush Creek cover the principal claims.

A ditch 4 miles long diverts water from Pioneer Creek just above Joe Bush Creek and carries it to the What Cheer Bar workings. A measurement was made on this ditch near Seattle Creek June 7, 1908, as follows: Gage height, 1.95 feet; discharge, 10.6 second-feet.

A gaging station was established on this stream at the intake of What Cheer Bar ditch June 7, 1908. Daily readings were taken by employees of Frank G. Manley.

Discharge measurements of Pioneer Creek at What Cheer Bar ditch intake, 1908.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*
June 7	C. C. Covert	0.95	10.8
June 21	A. V. Thorns	.65	4.0
August 8	C. E. Ellsworth	.50	2.6
August 19	do	.52	2.6
September 1	do	.70	7.2

Daily gage height and estimated discharge of Pioneer Creek at What Cheer Bar ditch intake, 1908.

[Elevation, 900 feet; drainage area, 8.1 square miles.]

Day.	June.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			0.55	2.9	0.70	4.7
2				2.9	.67	3.7
3				2.9	.78	6.2
4				2.9	.72	4.8
5			.55	2.9		4.4
6				2.8		4.0
7	0.95	10.8		2.7	.63	3.7
8	.85	7.9	.50	2.6		3.6
9	.83	6.6		2.6		3.4
10	.80	6.6		2.6		3.2

Daily gage height and estimated discharge of Pioneer Creek at What Cheer Bar ditch intake, 1908—Continued.

Day.	June.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
11	.75	5.6	.....	2.6	.....	3.0
12	.75	5.6	.....	2.6	.....	2.8
13	.70	4.7	0.50	2.6	0.51	2.6
14	.85	7.9	.....	2.7	.....	3.0
15	.95	10.8	.....	2.8	.60	3.4
16	.85	7.9	.....	2.9	.....	4.2
17	.80	6.6	.55	2.9	.....	5.0
18	.75	5.6	.....	2.9	.....	5.8
19	.75	5.6	.....	2.9	.80	6.6
20	.70	4.7	.....	2.9	.75	5.6
21	.65	4.0	.....	2.9	.....	.....
22	.65	4.0	.....	2.9	.....	.....
23	.60	3.4	.....	2.8	.....	.....
24	.60	3.4	.....	2.7	.....	.....
25	.60	3.4	.....	2.6	.....	.....
26	.....	3.4	.....	2.6	.....	.....
27	.....	3.4	.....	2.6	.....	.....
28	.....	2.9	.50	2.6	.....	.....
29	.....	2.9	.....	3.1	.....	.....
30	.55	2.9	.....	3.6	.....	.....
31	.....	.....	.....	4.1	.....	.....
Mean	.....	5.44	.....	2.52	.....	4.18
Mean per square mile	.....	.672	.....	.311	.....	.516
Run-off, depth in inches	.....	.60	.....	.36	.....	.39

NOTE.—As there was practically no rain in this section during July it is presumable that the discharge for the month averaged not to exceed 2.9 second-feet.

HUTLINANA CREEK.

Hutlinana Creek is tributary to Baker Creek about 7 miles above its mouth, near the southern border of the Baker Flats. Its course is in general parallel to that of Eureka Creek. For the first mile or two the stream flows nearly due north; it then turns gradually toward the west, passing the south slope of Wolverine Mountain, and finally takes a general southwesterly course to the mouth. It has a broad, gravelly bed with sharp banks and follows a winding course, making many abrupt turns in passing from one side of the valley to the other. In general, however, it keeps near the left side. The topography of Hutlinana Valley presents strong contrasts—from Wolverine Mountain, with an elevation of 4,600 feet, to the marshy, alluvial Baker Flats.

Above Elephant Creek the east side of Hutlinana Valley rises precipitously and is broken by fewer tributaries than the west side, which is cut by many small streams, and exhibits a gradual, bench-like slope for a considerable distance back from the stream, beyond which it rises rapidly to the summit of Elephant and Wolverine mountains. The gravelly valley bottom forms a water course of

such nature that during a period of protracted drought 50 per cent or even more of the run-off may pass beneath the surface. Many other streams in the Rampart region have the same characteristic feature.

The valley contains a heavy growth of timber, much of which is suitable for milling. A sawmill has been in operation on the creek, and, considering the value of sawed lumber, it is surprising that such work is not carried on more extensively.

About 1 mile below Elephant Gulch a hot spring rises in the bed of the creek of a temperature and size sufficient to prevent the creek from freezing for a considerable distance below, even during the intense cold of the winter months. In the vicinity of the spring there are several acres of warm ground, now covered with a luxuriant growth of large spruce, poplar, and birch, which on clearing would be suitable for agriculture. Mr. F. E. Diver has taken up a homestead about the spring, and during the summer of 1908 he constructed a large cabin that could be used as a road house, put under cultivation some small patches of ground, and successfully raised several varieties of vegetables. If paying mines should be developed along the creek, Mr. Diver would find a ready and profitable market for his produce.

Considerable exploring has been done near the headwaters of the creek, but the presence of ground water and the lack of suitable machinery have prevented systematic prospecting and the working of ground that, under more favorable conditions, might yield gold in paying quantities.

Prospecting with a churn drill was probably done on Hutlinana Creek during the winter of 1908–9.

A gage was installed June 9, 1908, on the left bank a short distance below Cairo Creek, from which readings were taken during the summer by F. E. Diver. On September 1, 1908, a gage was installed above Cairo Creek on the left bank, about 500 feet below the hot springs, from which all subsequent readings will be made.

Discharge measurements of Hutlinana Creek below Cairo Creek, 1908.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*
June 9	C. C. Covert	1.32	76.3
June 25	A. V. Thorns	1.00	41.2
August 19	C. E. Ellsworth	.50	10.5
September 1	do	.65	14.9

81007—IRR 228—09——6

Daily gage height and estimated discharge of Hutlinana Creek below Cairo Creek, 1908.

[Elevation, 1,050 feet; drainage area, 44.2 square miles.]

Day.	June.		July.		August.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1	.....	.....	0.90	32.0	0.60	12.8
2	.....	.....	.90	32.0	.....	12.7
3	.....	.....	.....	31.0	.....	12.6
4	.....	.....	.....	30.0	.....	12.5
5	.....	.....	.....	29.0	.....	12.4
6	.....	.....	.....	28.0	.....	12.3
7	.....	.....	.....	27.0	.....	12.2
8	.....	.....	.....	26.0	.....	12.1
9	1.30	74.0	.....	25.0	.....	12.0
10	1.30	74.0	.80	24.0	.....	12.0
11	.....	85.6	.80	24.0	.....	11.8
12	1.50	97.0	.80	24.0	.....	11.7
13	1.60	109	.....	24.0	.....	11.6
14	1.70	122	.80	24.0	.....	11.4
15	1.70	122	.80	24.0	.....	11.3
16	.....	109	.80	24.0	.....	11.2
17	1.50	97	.....	22.6	.....	11.0
18	1.40	85.6	.....	21.3	.....	10.8
19	1.30	74.0	.....	20.0	.50	10.5
20	.....	66.0	.....	18.7	.50	10.5
21	.....	59.4	.70	17.4	.50	10.5
22	1.10	51.8	.....	17.4	.....	.....
23	1.10	51.8	.70	17.4	.....	.....
24	1.10	51.8	.....	17.4	.....	.....
25	1.00	41.4	.....	17.4	.....	.....
26	.....	37.6	.70	17.4	.....	.....
27	.....	34.7	.....	15.8	.....	.....
28	.90	32.0	.....	14.3	.....	.....
29	.90	32.0	.60	12.8	.....	.....
30	.80	24.0	.....	12.8	.....	.....
31	.....	.....	.....	12.8	.....	.....
Mean	.....	69.6	.....	22.0	.....	11.7
Mean per square mile	.....	1.57	.....	.498	.....	.265
Run-off, depth in inches	.....	1.28	.....	.58	.....	.20

MISCELLANEOUS MEASUREMENTS.

Most of the miscellaneous measurements made in the Baker Creek drainage basin are given in the following table.

Ohio Creek and Elephant Gulch are small tributaries of Hutlinana Creek from the right near the headwaters. Goff and Applegate creeks, the two largest tributaries of Hutlinana Creek, enter it from the east about 12 miles from the head. Applegate Creek is said to have several good-sized thermal springs in its upper drainage which furnish the greater portion of the run-off during the low-water season.

The measurements on Hutlinana Creek below the mouth of Caribou Creek were made about 500 feet below the proposed ditch intake, as determined by surveys made during the summer of 1908 in connection with the project to convey water from Hutlinana Creek to the Baker Creek mines.

Miscellaneous measurements in Baker Creek drainage basin, 1908.

Date.	Stream and locality.	Drainage area.	Discharge.	Discharge per square mile.
		Sq. miles.	*Sec.-ft.*	*Sec.-ft.*
August 30	North Fork of Baker Creek below Wolverine Creek.	19.7	5.2	0.264
Do	Wolverine Creek 2 miles above mouth	6.2	2.1	.339
Do	Wolverine Creek at mouth	8.2	2.6	.317
August 22	New York Creek at trail crossing	17.3	[a] 1.4	
June 6	Thanksgiving ditch at outlet		11.1	
August 29	do		1.7	
June 7	What Cheer Bar ditch near Seattle Creek		4.0	
August 20	Hutlinana Creek below Caribou Creek	16.1	1.9	.118
September 2	do	16.1	3.1	.192
August 20	Ohio Creek at trail crossing	3.2	.93	.290
Do	Elephant Gulch at mouth	3.3	1.1	.333
Do	Goff Creek near mouth	11.4	2.4	.211
Do	Applegate Creek 1 mile above mouth	18.9	2.8	.148

[a] 1.7 second-feet diverted above point of measurement.

PATTERSON CREEK DRAINAGE BASIN.

Patterson Creek is formed by the junction of Sullivan and Cache creeks and is tributary to Tanana River about 40 miles below the mouth of Baker Creek. It drains an area of low relief, the most prominent feature of which is Bean Ridge on the south, which furnishes several small tributaries. Woodchopper Creek is tributary to Patterson Creek about 6 miles from the Tanana.

Sullivan Creek, the right fork of Patterson Creek, rises on the south slope of Roughtop Mount, and for about 10 miles flows a little west of south through a wide valley with gentle slopes and high, broad benches. Birch and spruce timber suitable for cabins and fuel is abundant in the lower valley.

Values were located on Sullivan Creek by Messrs. Snyder and Kemper January 1, 1907, just befow the mouth of Tufty Gulch, since which time work on Discovery and one or two other claims has been successfully carried on. The bench on the left side was prospected quite extensively during the summer of 1908, and values are said to have been found at several places. Lack of water is apt to seriously interfere with extensive operations along the present line of exploration. Some prospecting has been done on Cache Creek, but no values have been found.

A gage was established on Sullivan Creek August 4, 1908, 3 miles above the mouth, and readings taken by employees on the ditch, but as measurements were made only at low water no daily discharges can be computed.

Miscellaneous measurements in Patterson Creek drainage basin, 1908.

Date.	Stream and locality.	Drainage area.	Gage height.	Discharge.	Discharge per square mile.
		Sq. miles.	*Feet.*	*Sec.-ft.*	*Sec.-ft.*
August 4	Cache Creek at trail crossing	22.7		3.2	0.141
Do	Sullivan Creek 3 miles above mouth	20.7	0.80	5.7	.275
August 24	do	20.7	.70	4.5	.217
August 26	Quartz Creek near mouth	8.0		2.8	.350
August 25	Woodchopper Creek at trail crossing	19.7		4.4	.223

FIFTYMILE RIVER AT WHITE HORSE.

Since 1902 the White Pass and Yukon Railroad Company has kept daily records of the stage of Fiftymile River at White Horse, together with the dates of opening and closing of navigation. In 1908 members of the United States Geological Survey, on their way to the interior of Alaska, made the following measurements of the river at this point.

June 10, gage height, 9½ inches; discharge, 4,490 second-feet.

June 16, gage height, 16⅜ inches; discharge, 5,100 second-feet.

Drainage area, 7,630 square miles; discharge, 0.588 and 0.668 second-foot per square mile, respectively.

COMPARATIVE DISCHARGE OF DIFFERENT AREAS.

In order to afford a comparison of the discharge of different drainage areas in the Yukon-Tanana region during 1907–1908 the following tables have been prepared, showing the minimum daily flow and the mean weekly supply in second-feet and, for some streams, in second-feet per square mile. These tables can be used in estimating the discharge of streams in this region having similar drainage areas, but such estimates will only roughly approximate the true discharge because of the variation of the controlling conditions in the individual drainage basin. The diagram (fig. 3) is plotted from the table of discharge in second-feet per square mile on page 89. It illustrates graphically in weekly periods the discharge of various streams in second-feet per square mile, and it has been prepared for use in connection with the tables of comparative discharge.

A table of drainage areas of a few of the important streams in this region other than those studied is given on page 89. If this table is used in connection with the precipitation records and the tables of comparative discharge, it may prove useful in making rough estimates of minimum stream flow in areas for which no data have been obtained.

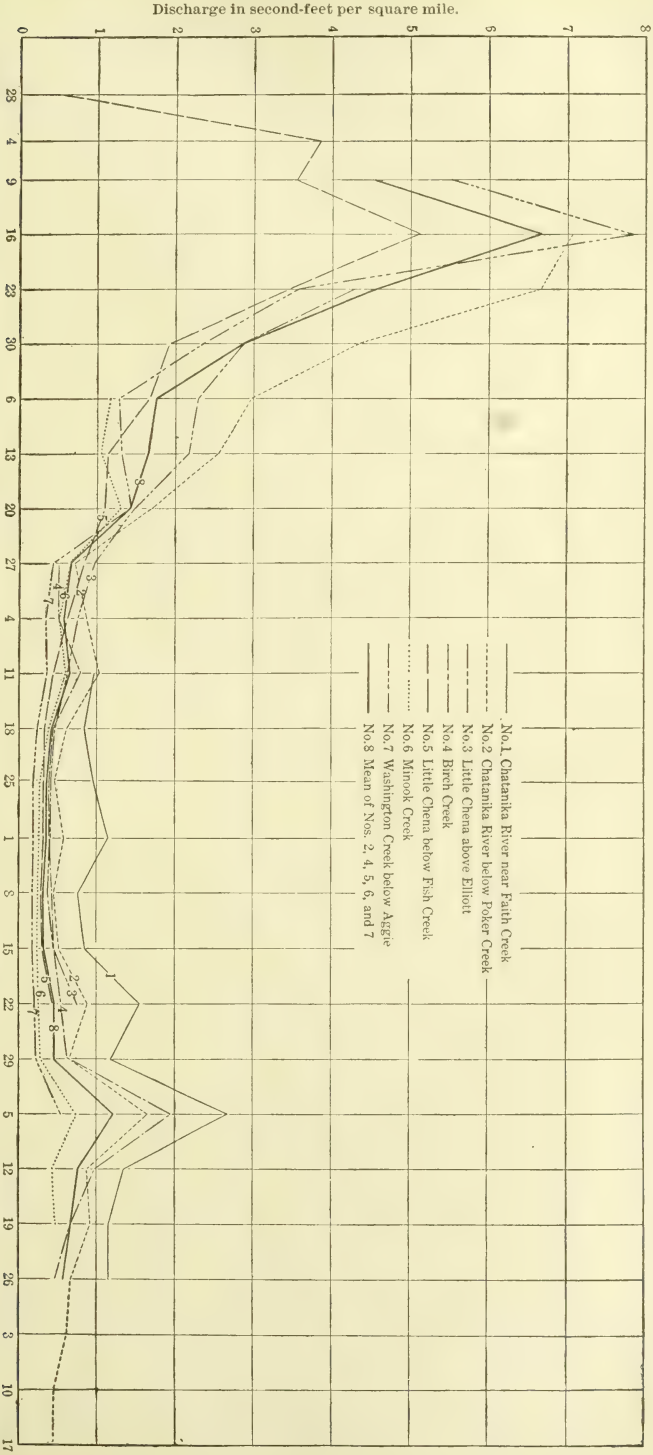


FIGURE 3.—Diagram showing mean weekly discharge in second-feet of streams in Yukon-Tanana region.

Estimated minimum daily flow of streams in Yukon-Tanana region, 1907–1908.

FAIRBANKS DISTRICT.

Stream and locality.	Elevation.	Date.	Minimum flow.	Drainage area.	Minimum discharge per square mile.	Duration of record.
	Feet.	1907.	*Sec.-feet.*	*Sq. miles.*	*Sec.-foot.*	
Little Chena River above Elliott Creek.	800	July 22–25, 29–31.	42	79	0.532	July 22–Sept.10.
Elliott Creek above Sorrels Creek	800	July 31	2.5	13.8	.181	Do.
Sorrels Creek above mouth	800	do	6	21	.286	Do.
Fish Creek above Fairbanks Creek.	925	July 30–31	18	39	.462	Do.
Faith Creek at mouth	1,400	July 10	19.2	51	.376	June 20.
McManus Creek at mouth	1,400	July 10–12	15	80	.188	Do.
Chatanika River below Faith Creek.	1,350	July 31	54	132	.409	July 17–Sept.30.
Kokomo Creek near mouth	750	July 23, 30–31	7.9	26	.304	July 9–Aug. 14.
Chatanika River below Poker Creek.	700	July 4–7, 10	167	456	.366	June 20–Oct. 14.
		1908.				
Little Chena River above Elliott Creek.	800	Aug. 11	28	79	.354	May 20–Aug. 26.
Little Chena River below Fish Creek.	700	Aug. 12–13	59	228	.259	May 1–Aug. 27.
Elliott Creek above Sorrels Creek.	800	Aug. 4–7, 9–13.	4.4	13.8	.319	May 20–Aug. 26.
Sorrels Creek near mouth	800	Aug. 3–14	10	21	.476	Do.
Fish Creek above Fairbanks Creek.	925	Aug. 21–Sept. 12–13.	12	39	.308	May 22–Aug. 27.
Fish Creek at mouth	700	July 17–18, 31–Aug. 6, 12–13	22	90.2	.244	May 1–Aug. 27.
Miller Creek near mouth	750	Aug. 12–13	4.0	15	.267	May 13–Aug. 27.
Chatanika River near Faith Creek.	1,350	July 21–22	82	132	.621	July 13–Sept.30.
Chatanika River below Poker Creek.	700	Oct. 15–16, 21	179	456	.386	May 16–Oct. 21.
Washington Creek above Aggie Creek.	600	July 23	18	117	.154	May 23–Sept. 4.
Washington Creek below Aggie Creek.	600	July 23	24	153	.157	May 5–Sept. 4.
Aggie Creek above mouth	600	July 31	4.5	35.8	.126	May 23–Sept. 4.

CIRCLE DISTRICT.

		1908.				
Birch Creek at Fourteenmile House.	700	Aug. 8	825	2,150	0.384	June 20–Sept.10.
Mammoth Creek at Miller House	1,700	Oct. 10–13	13.0	37.1	.350	Sept. 8–Oct. 13.
Porcupine Creek below Bonanza Creek.	1,900	Aug. 7	15.5	39.9	.388	July 4–Aug. 10.

RAMPART DISTRICT.

		1908.				
Minook Creek above Little Minook Creek.	425	Aug. 15	80	130	0.231	June 7–Sept.22.
Hoosier Creek at claim 11 above.	600	Aug. 16–31–Sept. 21.	4.7	25.7	.183	Aug. 16–Sept.21.
Little Minook Creek at claim 9 above.	1,000	July 17–Aug.1.	.62	5.9	.105	June 21–Sept.15.
Hunter Creek at claim 17 above.	600	Aug. 23	3.7	33.4	.111	Aug. 11–Sept.12.
Troublesome Creek below Quail Creek.	1,750	Sept. 25	4.0	43.2	.093	Aug. 12–Sept.25.
New York Creek at Thanksgiving ditch intake.	800	June 30–July 14, Aug. 9–17.[a]	.7	4.7	.149	June 6–Sept.20.
Thanksgiving ditch near outlet	800	Aug. 12–16	1.6			Do.
California Creek branch of Thanksgiving ditch near intake.	800	July 2, 8	1.8			Do.
Pioneer Creek at What Cheer Bar ditch intake.	900	Aug. 8–13, 25–28; Sept. 13.	2.6	8.1	.321	June 7–Sept.20.
Hutlinana Creek below Cairo Creek.	1,050	Aug. 19–21	10.5	44.2	.238	June 9–Aug. 21.

[a] No records July 15 to August 7, inclusive; discharge may have been less than 0.7 second-foot.

Mean estimated weekly water supply, in second-feet, from Little Chena and Chatanika River basins, Fairbanks district, 1907.

Date.	Available for use by diversion at elevation 1,350 feet.	Available for use by pumping at elevation 700 feet.	Available for use by diversion at elevation 800 to 925 feet.				
	Chatanika River near Faith Creek.	Chatanika River below Poker Creek.	Little Chena River above Elliott Creek.	Elliott Creek above Sorrels Creek.	Sorrels Creek near mouth.	Fish Creek above Fairbanks Creek.	Total in Little Chena drainage basin.
June 17–23	86						
June 24–30	64	216					
July 1–7	44	178					
July 8–14	36	190					
July 15–21	64	250					
July 22–28	67	224	52	7	12	24	95
July 29–August 4	84	540	80	12	18	55	165
August 5–11	138	516	110	12	24	42	188
August 12–18	85	313	73	10	16	26	125
August 19–25	110	260	56	6	10	24	96
August 26–September 1	180	413	90	11	18	26	145
September 2–8	130	324	82	9	15	26	132
September 9–15	592	1,360					
September 16–22	451	1,480					
September 23–29	238	737					
September 30–October 6		655					
October 7–13		415					
Mean	158	504	78	10	16	32	136
Maximum	592	1,480	110	12	24	55	188
Minimum	36	190	52	6	10	24	95

Mean estimated weekly water supply, in second-feet, from Little Chena, Chatanika River, and Washington Creek basins, Fairbanks district, 1908.

Date.	Available for use by diversion at elevation 1,350 feet.	Available for use by pumping at elevation 700 feet.	Available for use by diversion at elevation 800 to 925 feet.					Available for use by diversion at elevation 600 feet.
	Chatanika River near Faith Creek.	Chatanika River below Poker Creek.	Little Chena River above Elliott Creek.	Elliott Creek above Sorrels Creek.	Sorrels Creek near mouth.	Fish Creek above Fairbanks Creek.	Total in Little Chena drainage basin.	Washington Creek below Aggie Creek.
May 16–19		3,220						[a] 1,200
May 20–26		3,020	339	93	87	[b] 162	681	546
May 27–June 2		1,980	227	30	55	98	410	360
June 3–9		1,360	181	15	31	79	306	198
June 10–16		1,160	172	25	34	50	281	200
June 17–23		775	118	9.3	54	44	225	226
June 24–30		331	77	8.9	48	42	176	68
July 1–7		394	59	6.8	33	30	129	52
July 8–14	[c] 150	468	48	5.3	24	23	100	56
July 15–21	110	278	38	4.6	15	16	74	35
July 22–28	127	207	33	4.5	11	13.5	62	29
July 29–August 4	151	271	32	4.5	11	13.5	61	31
August 5–11	101	211	31	4.4	10	13.5	59	29
August 12–18	112	236	36	45	12	14	66	29
August 19–25	202	402	[d] 59	[d] 46	[d] 16	17	97	32
August 26–September 1	157	306						35
September 2–8	351	743						[e] 85
September 9–15	176	407						
September 16–22	153	423						
September 23–29	[f] 152	313						
September 30–October 6		284						
October 7–13		228						
October 14–21		205						
Mean	162	749	104	15.7	31.5	44	195	225
Maximum	351	3,220	339	93	87	162	681	1,200
Minimum	101	205	31	4.4	10	13.5	59	29

[a] May 13–19. [b] May 22–26. [c] July 13–14. [d] August 19–26. [e] September 2–4. [f] September 23–30.

Mean estimated weekly water supply, in second-feet, of streams in the Circle district, 1908.

Date.	Birch Creek at ferry.	Porcupine Creek below mouth of Bonanza Creek.	Mammoth Creek at Miller House.
June 26–July 3	1,240		
July 4–10	1,600	73.5	
July 11–17	1,160	45.3	
July 18–24	936	21.5	
July 25–31	870	19.7	
August 1–7	850	16.0	
August 8–14	1,060	[a] 19.5	
August 15–21	964		
August 22–28	1,280		
August 29–September 4	2,110		
September 5–11	4,090		[b] 32.5
September 12–18	1,510		21.9
Septemebr 19–25	1,290		23.3
September 26–October 2	[c] 942		14.6
October 3–9			14.4
October 10–13			13.0
Mean	1,420	32.6	17.1
Maximum	4,090	73.5	32.5
Minimum	859	16.0	13.0

[a] August 8–10. [b] September 8–11. [c] September 26–29.

Mean weekly water supply, in second-feet, of streams in the Rampart district, 1908.

Date.	Minook Creek above Little Minook Creek.	Hoosier Creek at claim 11 above.	Little Minook Creek at claim 9 above.	Hunter Creek at claim 17 above.	Troublesome Creek below Quail Creek.	New York Creek at Thanksgiving ditch intake.	California Creek branch of Thanksgiving ditch near intake.	Thanksgiving ditch near outlet.	Pioneer Creek at What Cheer Bar ditch intake.	Hutlinana Creek below Cairo Creek.
June 6–12	[a] 136					4.4	4.6	8.4	[a] 7.2	[b] 82.
June 13–19	164					3.4	4.6	8.7	7.0	103
June 20–26	136		[c] 3.1			2.8	7.2	6.0	3.8	51.4
June 27–July 3	75		1.6			1.0	2.3	2.7	3.0	31.1
July 4–10	77		9.9			.8	2.1	2.3		27.0
July 11–17	63		5.0			[d] .8	[d] 2.1	[d] 2.2		23.8
July 18–24	41		.62							18.5
July 25–31	35		.62							14.8
August 1–7	36		.78						2.9	12.5
August 8–14	32		.71	[e] 4.8	[f] 6.7	.8	2.1	1.7	2.6	11.8
August 15–21	33	[g] 4.7	.82	4.6	6.6	1.5	2.4	2.5	2.9	10.8
August 22–28	34	4.7	.87	4.4	7.5	1.4	2.2	2.4	2.7	
August 29–September 4	62	16.4	4.4	12.2	20.9	3.9	3.9	5.6	4.6	
September 5–11	83	14.8	2.8	[h] 14.9	37.6	3.8	4.3	6.0	3.6	
September 12–18	58	8.5	[i] 1.6		16.1	3.3	4.7	5.1	3.8	
September 19–25	[j] 33	[k] 7.3			8.5	[l] 6.8	[l] 4.8	[l] 10.4	[l] 6.1	
Mean	68.6	9.4	2.53	8.18	14.8	2.67	3.64	4.92	4.18	35.2
Maximum	164	16.4	9.9	14.9	37.6	6.8	7.2	10.4	7.2	103
Minimum	32	4.7	.62	4.4	6.6	.8	2.1	1.7	2.6	10.8

[a] June 7–12.
[b] June 9–12.
[c] June 21–26.
[d] July 11–14.
[e] August 11–14.
[f] August 12–14.
[g] August 16–21.
[h] September 5–12.
[i] September 12–15.
[j] September 18–22.
[k] September 18–21.
[l] September 19–20.

Mean estimated weekly discharge, in second-feet, per square mile of streams in Yukon-Tanana region, 1908.

Date.	Chatanika River below Poker Creek (drainage area 456 square miles).	Little Chena River below Fish Creek (drainage area 228 square miles).	Washington Creek below Aggie Creek (drainage area 147 square miles).	Hutlinana Creek below Cairo Creek (drainage area 130 square miles).	Minook Creek above Little Minook Creek (drainage area 130 square miles).	Birch Creek at Fourteenmile House (drainage area 2,150 square miles).	Mean.	Chatanika River near Faith Creek (drainage area 132 square miles).	Little Chena River above Elliott Creek (drainage area 79 square miles).	Mean.
May 1–5		3.84								
May 6–12		3.53	5.51				4.52			
May 13–19	7.03	5.10	7.84				6.66			
May 20–26	6.61	3.44	3.57				4.54		4.29	
May 27–June 2	4.34	1.92	2.35				2.87		2.87	
June 3–9	2.98	1.69	1.29	1.67	1.18		1.76		2.29	
June 10–16	2.52	1.14	1.31	2.32	1.05		1.67		2.18	
June 17–23	1.70	1.10	1.48	1.57	1.30		1.43		1.49	
June 24–30	.72	.83	.44	.82	.68	.51	.67		.98	
July 1–7	.86	.62	.34	.68	.51	.50	.58		.75	
July 8–14	1.02	.45	.37	.55	.61	.80	.63	.97	.61	.79
July 15–21	.61	.33	.23	.48	.38	.46	.42	.83	.48	.66
July 22–28	.45	.31	.19	.38	.28	.40	.35	.96	.42	.69
July 29–August 4	.59	.32	.20	.28	.27	.40	.36	1.15	.41	.78
August 5–11	.46	.29	.19	.27	.26	.45	.32	.76	.39	.58
August 12–18	.52	.31	.19	.25	.24	.46	.33	.85	.46	.66
August 19–25	.88	.43	.21	.24	.26	.54	.43	1.55	.75	1.15
August 26–September 1	.67		.23		.28	.64	.46	1.19		
September 2–8	1.63		.55		.73	1.93	1.21	2.66		
September 9–15	.89				.44	.99	.77	1.33		
September 16–22	.92				.48	.66	.69	1.16		
September 23–29	.68					.47	.58	1.15		
September 30–October 6	.62									
October 7–13	.45									
October 14–21	.45									

Drainage areas of streams in interior of Alaska.

	Square miles.
Fiftymile River at White Horse, Yukon Territory	7,630
Yukon River at Dawson, Yukon Territory	115,000
Yukon River at Fort Yukon	177,000
Yukon River at Rampart	206,000
Yukon River at mouth	322,000
Fortymile Creek 3 miles below Fortymile telegraph station[a]	1,620
Fortymile Creek at mouth	6,350
Charley River at elevation 2,200 feet [b]	449
Charley River at elevation 1,000 feet [c]	1,470
Charley River at mouth	1,760
Birch Creek at mouth	3,090
Preacher Creek at mouth	1,100
Beaver Creek at mouth	5,360
Tanana River at mouth	42,000
Salcha River at the Splits [d]	1,290
Salcha River at mouth	2,150

[a] 100 feet fall in 4 miles.
[b] 400 feet fall in 9 miles.
[c] 200 feet fall in 5 miles.
[d] 200 feet fall in 8 miles.

HYDRAULIC DEVELOPMENT.

DITCH AND PIPE LINES IN ALASKA.

No ditch project of any considerable magnitude has yet been undertaken in the Yukon-Tanana region. About half a dozen short ditches have been built on tributaries of Birch, Minook, Patterson, and Baker creeks, but none in the Fairbanks district have advanced beyond the stage of preliminary investigation. It is probable, however, that in the next few years large waterways will be constructed either for hydraulicking or, more likely, for generating hydro-electric power. Engineers contemplating such work in the interior of Alaska can consider with profit the experiences of ditch builders in Seward Peninsula where hundreds of miles of water conduits have been constructed under a wide range of conditions. Henshaw[a] has described construction methods and difficulties in the Nome and Kougarok region as follows:

Ditches are usually built so as to follow the contour approximately with grades limiting the velocity to about 2 feet per second, which is as high as the material in this section will stand without scour. The ditches are therefore for the most part on slopes, and are constructed by making a cut from 12 to 18 inches deep to grade at the lower bank. This bank is then built up by material from the excavation. The slopes of the banks are from 1:1 to 1½:1, depending on the material.

The work of constructing a ditch is usually divided into three classes—team work, pick-and-shovel work, and rock work. Teams may be used in handling dry soil that contains only medium-sized rock. This is the fastest method, and the compacting of the lower banks by the horses and scrapers makes it much tighter than when the dirt is thrown in loose. Pick and shovel are used in loose rock, in wet soil, and in frozen ground from which the top is removed as it thaws from the surface. Rock must be blasted, unless it is fissured limestone, which may be loosened with the crowbar, or decomposed schist, which yields to the picks. In building through solid rock a shelf is blasted out about 1 foot below grade and wide enough to carry the ditch and the lower bank, which is built of rocks. The bottom and sides are lined with sod about 1 foot thick, and are puddled with clay. In rock slide the method is similar. A good example of this kind of construction was seen on the Grand Central branch of the Miocene system. The ditch was built through a pile of large bowlders, unmixed with any soil or gravel. A trench was made 1 foot deeper and 2 feet wider than the finished ditch. The sides of the trench were lined with a slope wall, laid 1 to 1, to a height of 4 or 5 feet. The outer slope of the lower bank was also rock wall, laid somewhat flatter. The ditch will be lined with sod and will be tight and permanent.

The use of sod is very common and economical and saves much piping and fluming that would otherwise be necessary. The sod in a short time settles and knits together, and thus becomes a very serviceable bank. It will not cut or wear out, and the older it gets the better it becomes. In this way a ditch can be made over perpetually frozen ground where otherwise it would be impossible. Much ditch has to be constructed over loose stones with little or no sediment between them. Such ditches must be lined with sod and all holes must be filled by tamping sod into them as far as possible. This being done, it will be found that the water traveling through the

[a] Water-supply investigations in Alaska, 1906–1907: Water-Supply Paper U. S. Geol. Survey No. 218, 1908, p. 72.

ditch will deposit sediment over the sod and that after a little while it will become tight.

Canvas is also used as a lining to make a ditch water-tight. Willows with the tops left out, so that they may grow, are utilized in embankments with success.

In construction over "glacier," which is the term used for frozen muck mixed with ground ice, the ditch is either built wholly on top of the sod covering or an excavation is made and lined with sod. Ditches over this material are expensive to maintain, owing to the thawing of the ice by the running water.

One of the most interesting pieces of construction over glacier is the flume on the Miocene ditch. This flume is 1,100 feet long and has a width of 8 feet and a depth of 28 inches. It was constructed in 1901, and is now in practically perfect alignment, both horizontal and vertical, and no repairs have been necessary on it. In putting in the foundation, trenches were dug 3 or 4 feet deep in the frozen ground, which was practically all ice. The excavated material was covered to protect it from thawing. A sill was laid in the bottom of the trench and the uprights fastened to this sill. The excavated material was then replaced in the trenches and froze again into the original condition. Sod was carefully placed over the trench. The uprights were then sawed off to grade and the flume constructed on them.

Inverted siphons are built across deep ravines where their use will save expense and reduce loss by seepage. Most of these are riveted steel pipe. Joints are made by lapping the ends from 4 to 6 inches. Siphons must be weighted down and protected by rock to prevent injury by frost and snowslides. During 1906 two siphons were built on the Seward ditch across Clara and Hobson creeks, continuous wood-stave pipes with steel bands being used.

On account of the rapid surface run-off during hard rains, it is necessary to have waste gates at short intervals. The most common waste gates consist either of a flume as deep as the bottom of the ditch, in which the height of the water is regulated by flashboards, or of a long weir, laid on the ground surface, which will spill the water when it reaches a certain level.

Ditch intakes consist of a dam or barrier across the stream, containing one or more waste gates, and head-gates for regulating the flow into the ditch. In order to divert the entire flow of a stream, a bed-rock dam must be built to stop the ground flow through the gravelly beds. Such a dam is made by cutting a trench across the stream bed, extending down to an impervious stratum, and filling it with sod, which is carefully laid and tamped. The dam should be protected from erosion with large flat rocks or riprap.

Frozen ground, inadequate facilities for transportation, and the high cost of help[a] and supplies make ditching very expensive. To the first cost of a ditch should be added the cost of maintenance for the first three years, during which time extensive repairs are necessary. On many ditches these repairs cost as much as the first construction. At the end of three years ditches are, as a rule, in fairly permanent condition and the cost of maintenance is greatly reduced. Such information as could be obtained shows that the cost of a ditch carrying from 1,000 to 2,000 inches, including the first three years' maintenance, is from $5,000 to $10,000 per mile. Owing to dangers from washouts and landslides it is necessary to have the ditch constantly patrolled.

Owing to the frozen condition of the ground it is not practicable to use ditches much before the 1st of July, as the surface does not become fully thawed until that time, and during the thawing period the ground becomes very soft and there is great danger of damage by washouts.

The above discussion was written before Mr. Henshaw had visited the Fairhaven and Candle ditches in the Fairhaven district. The condi-

[a] Laborers receive $5 per day and board; blacksmiths, etc., $6.

tions encountered on these waterways were much more difficult than in the country a hundred miles or so farther south; in fact, there is more difference between some of the ground in the Fairhaven precinct and the slopes of the Nome River Valley than between that of Nome River and the unfrozen soil of temperate latitudes. The following are extracts from the descriptions of the Fairhaven and Candle ditches.[a]

The [Fairhaven] ditch has a grade of 4.2 feet to the mile and was built 11 feet wide on the bottom, 1 foot in cut at the lower side, and with a 4-foot lower bank. The removal of 1 or 2 feet of the upper moss and soil put the bottom of the ditch into ground ice and muck, much of the ice being fairly pure. This material thawed when the water was turned in and a large part of the bottom of the ditch has settled at least 2 feet and has widened in many places to 15 or 20 feet, or more. As the upper bank thawed, the material was thrown against the lower bank to protect it and keep the water from getting under it. Practically the whole of the upper ditch, and at least three-fourths of the lower ditch, including all the upper 6 or 8 miles, is built in frozen ground of this character. Where the lower ditch is built around the steep gulches that carry the eastern tributaries of the Pinnell the northerly slopes of the gulches are covered with muck, but the southerly slopes are made up of a more solid clay and decomposed mica schist. Along the upper ditch lava bowlders are present in the muck from the surface to bed rock. At some places the material encountered was composed of angular fragments of lava with little soil between them. Above and below Snow Gulch, the lowest tributary of Pinnell River which the ditch crosses, there are short pieces of rock work. The rock is much shattered and could have been loosened with picks if it had not been frozen. Much difficulty was experienced in making the rock work water-tight on account of the lack of good sod, as the surface covering is commonly decayed moss or peat containing much fibrous matter with little earthy material to give solidity and will generally float even though saturated with water

The [Candle] ditch is 6 feet wide at the intake, increasing to 9 feet at the lower end. It has a grade of 3.7 feet to the mile, a capacity of 20 to 30 second-feet, and an elevation at the penstock of 249 feet above Kiwalik River. A cut of 9 inches was made on the lower side; this gave a low ditch bank in places where the ground was solid, but in the frozen muck the ditch bottom has settled 1 to 2 feet. The material encountered varied greatly. Near the upper end there were 2 miles of decomposed mica schist; below Burnside Creek there was some rocky ground with too little sediment to make the ditch tight without a great deal of work. Repair work in such places was difficult on account of the general lack of good sod. The portions of the ditch built over the muck gave the least trouble in building. A berm 1 foot wide was left on the lower bank between the cut and fill, and formed a protection for the inside of the bank when the bottom settled.

FAIRBANKS DISTRICT.

GENERAL CONDITIONS.

In the Fairbanks district mining has been carried on either by "open cuts" or by "drifting," as best suits the local conditions. The upper portions of the creeks usually favor the "open-cut" method, as the bed rock ranges only from 8 to 20 feet befow the surface. In the lower reaches, where the pay streak is 50 to 250 feet underground, with 25 to 200 feet of overburden, "drifting" seems

[a] Henshaw, F. F., Mining in the Fairhaven precinct: Bull. U. S. Geol. Survey No. 379, 1909, pp. 359, 367.

the only solution. The work being underground, where protection from severe weather is assured, this portion of the camp is active in winter as well as in summer. The pay gravel is hoisted to the surface and dumped in large piles, where it awaits the spring break-up for sluicing, when high water follows the melting of the accumulated snow. (See Pl. III.)

In the Fairbanks district little work has been done as yet toward constructing ditch lines from larger drainage areas for additional water supply. Present developments are confined to small ditches, which convey water to mines in their immediate vicinity on the creeks from which they draw their supply. The camp lies in three drainage basins, or valleys, separated by high dividing ridges, and in order to supply the producing creeks in one valley with water by ditch line from another the ditch must have a high elevation, which throws its intake so far into the headwaters that there is only a small drainage area from which to draw the supply.

PROPOSED DITCH LINES.

On account of its elevation, the upper Chatanika drainage basin has been more carefully considered as a possible source of water for a ditch line to the mining camps than any other drainage area within a reasonable distance of the Fairbanks district. The supply from this stream, however, would require more than 100 miles of ditch, difficult to construct and maintain, and would, by reason of its low head, benefit only a small number of producing creeks.

Numerous surveys and reports have been made favoring the construction of ditch lines from this drainage basin. The first plan proposed a ditch along the left bank of the Chatanika that would deliver water to Pedro Dome at an elevation of about 1,800 feet, which would be necessary in order to supply water to Goldstream and Fairbanks creeks on the other side of the divide. The intake of such a ditch would have an elevation of about 2,000 feet, or 600 feet higher than the mouth of Faith and McManus creeks, where records of stream flow were kept during the seasons of 1907–8. The drainage area above this intake would be about 100 square miles, or about 25 per cent less than at the point where measurements were made. The records kept during the season of 1907 prove conclusively that had the proposed ditch been built it would have had, instead of a daily supply of 125 second-feet, as was estimated, less than half that amount during the greater part of the open season.

During 1907 surveys were made for a proposed ditch with an intake at the junction of Faith and McManus creeks. This ditch would deliver water to the camps at an elevation of about 1,200 feet—much too low to supply water outside of the Chatanika drainage basin. The tables on page 87 show the weekly supply that would have been

available for such a ditch during 1907–1908, and the tables on page 102 show the number of days of deficient flow without storage and the amount of storage necessary to have maintained in the ditch a flow of 75, 100, or 125 second-feet, for the same period.

WATER POWER.

Power developments are possible in the Fairbanks district on several streams, as shown by records kept in the Chatanika and Little Chena drainage basins for two seasons, and on Washington Creek in the spring of 1908.

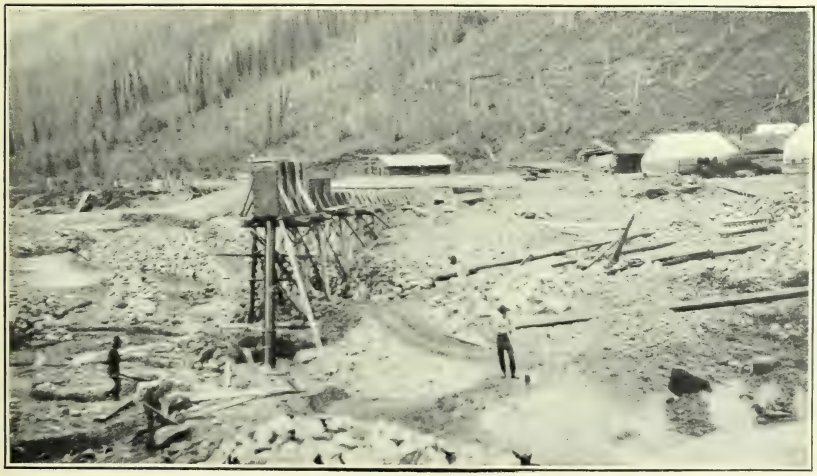
If storage can be provided in the headwaters the Chatanika project is the most feasible. The table on page 100 shows the horsepower (80 per cent efficiency) that could have been developed in 1907 from water supply of the Chatanika at the junction of Faith and McManus creeks and below Poker Creek. This table shows also the duration in days for different rates of flow. The tables on page 102 show the storage that would have been necessary for the maintenance of a daily flow of 100 second-feet near Faith Creek and of about 220 second-feet below Poker Creek, which would furnish 9.1 and 20 horsepower per foot of fall, respectively.

By constructing a ditch for 12 or 15 miles along the Chatanika, diverting water from a point near the junction of Faith and McManus creeks, a head of about 400 feet could be obtained. A daily flow of 100 second-feet under a 400-foot head would develop 3,640 horsepower on the turbines. The plant at Poker Creek would require about 8 miles of ditch, which would give a head of approximately 100 feet and would develop 2,000 horsepower. The power from the upper plant could be transmitted to the lower and the combined development of, say, 5,600 horsepower, could be used for pumping water to the producing creeks.

In the Little Chena drainage basin it is proposed to gather the water from the upper tributaries, at an elevation of about 900 feet, and convey it by ditch line to a point in the lower drainage area, on the right bank of the river, where a fall of nearly 200 feet can be obtained. A portion of the water so collected is to be used in developing electric power for transmission to the producing creeks, and the excess water will be carried by ditch line to Smallwood and Nugget creeks and there used for mining.

Washington Creek has also been considered as a source of power. During 1908 daily records were kept at the junction of Aggie Creek, below which there is a fall of approximately 200 feet in about 8 miles, and topographic conditions are favorable for ditch-line construction. The records, however, indicate an insufficient supply of water for power development, but if storage could be provided it is possible that the minimum daily flow could be brought to a point which would warrant development.

A. HYDRAULICKING ON EAGLE CREEK.



B. HYDRAULIC ELEVATOR ON HOOSIER CREEK.

CIRCLE DISTRICT.

GENERAL CONDITIONS.

Most of the mining in the Birch Creek region, where bed rock lies only 10 to 20 feet below the surface, is carried on by the "open-cut" method. The situation for hydraulicking is more favorable than is that in the Fairbanks or Rampart regions. The camps on Mammoth and Eagle creeks lie on streams of relatively high gradients. Consequently the water supply, though small, can be delivered to the mining property by comparatively short ditch lines, which give high heads for operating.

Up to 1906 practically the only hydraulic development in this district was a small plant on North Fork of Harrison Creek, but this project proved a failure. However, considerable construction work was done in the Birch Creek region during 1908.

EAGLE CREEK.

The ditch started by Berry & Lamb in 1907 was finished in 1908. A short ditch taps Miller Fork of Eagle Creek about 1 mile above its mouth and carries the water around to a storage reservoir on Mastodon Fork. From this point another small ditch carries the water about 2 miles along the left side of Eagle Creek to a pressure box, where a 210-foot head is obtained for hydraulicking. The water is conveyed to the mines through 4,200 feet of pipe line. This ditch was not completed until early in July, and the water from the spring break-up was therefore not utilized. The storage reservoir was not finished until the end of the season.

The method employed at the Eagle Creek plant differs somewhat from the hydraulic methods usually practiced in Alaska. A channel was first ground sluiced along the bed of the creek, and in this the sluice boxes were set. On the side of the sluice box opposite the pipe line an iron back stop was erected. The plan is to elevate the auriferous gravels by use of water direct from the nozzles. This method requires at least two nozzles in operation at the same time—one to wash the gravel against the back stop, from which it falls into the sluice boxes, and the other to furnish at the head of the boxes water sufficient for sluicing. (See Pl. VI, *A*.)

PORCUPINE CREEK.

During the summer of 1908 Berry & Lamb constructed a portion of a ditch that, when completed, will be used for hydraulicking Mammoth Creek flats from the junction of Mastodon and Independence creeks to the junction of Mammoth and Porcupine. The present ditch has its intake on Bonanza Creek at an elevation about 250 feet above the mouth, and follows along the right bank of Bonanza and

Porcupine creeks for about 6 miles to a point opposite Miller House, where, during the winter of 1908–9, a hydraulic plant will be installed for operations next season. The ditch was built by the use of horses and scrapers, is 7 feet wide on the bottom, and has a grade of 5 feet to the mile. The operating head will be about 500 feet. It is proposed during the coming season to extend the intake around to Porcupine Creek and the outlet to the mouth of Mastodon Creek.

RAMPART DISTRICT.

GENERAL CONDITIONS.

Mining in this district, like that in the Birch Creek region, is mostly by the "open-cut" method. On the Minook Creek side it is carried on by hydraulicking, by the use of hydraulic elevators (Pl. VI, *B*), and by splash dams (Pl. VII, *B*). In the Baker Creek group the water is used for ground stripping and washing the gravels that are shoveled to the sluice boxes. (See Pl. VII, *A*.)

The water-supply situation is quite similar to that in the Fairbanks section. Most of the mines are located on small streams, and many of them are near the headwaters. There is in the vicinity of nearly every mine in the district sufficient water for pumping, but, even if the supply at the point of working is sufficient, it is not in position to be used under pressure, and to get sufficient head for hydraulicking or elevating, the water must either be pumped or diverted at such an elevation that the supply available is of necessity small because of the small drainage area above the diversion point. The larger streams have comparatively low gradients, and long conduits are therefore necessary to bring the water to a point where a working head can be obtained. Present data fail to show where any extensive system of ditch construction for carrying water to the mines is warranted.

MINOOK CREEK GROUP.

GENERAL CONDITIONS.

The mines on Minook Creek have a total supply of water larger than those on Baker Creek, but as many are being worked by hydraulic methods, they are perhaps no better off than their neighbors on the south side of the divide. Minook Creek has been considered as a possible source of supply for the mines on its lower tributaries, but from a careful study of the situation in connection with the results of stream measurements in this locality in 1908, it is evident that a ditch line which would carry water to a sufficient elevation must have its diversion point very near the head of the creek, where the drainage area would be utterly inadequate to furnish a supply that would warrant the construction of 10 to 15 miles of ditch. In

A. SHOVELING IN ON THANKSGIVING CREEK.

B. SPLASH DAM IN OPERATION ON LITTLE MINOOK CREEK.

this section, as elsewhere in the Yukon-Tanana region in 1908, the work was very much hampered by lack of water, and during July and August practically nothing was done.

HUNTER CREEK.

On Hunter Creek two hydraulic plants were in operation during 1908. The plant on Discovery claim has 5,200 feet of riveted steel pipe, ranging in diameter from 20 to 14 inches, 2,300 feet of flume, and 200 feet of ditch. The working head is 105 feet, and the delivery about 400 miner's inches. The plant on claim 17 above has 3,300 feet of flume and 3,000 feet of ditch, an available head of 90 feet, and a delivery of 300 inches.

LITTLE MINOOK CREEK.

On Little Minook Creek the overburden is removed by the action of automatic splash dams (Pl. VII, *B*) operating intermittently, the time interval depending upon the stage of the stream. A log retaining dam is constructed, in the center of which is a spillway closed by an automatic gate which revolves about a horizontal axis. The gate has a vertical dimension of 13 above to 6 below this axis, and an outward slope of 2½ inches to 1 foot. On reaching a certain height the water above the gate causes it to swing forward, allowing a sudden rush of water which is directed by means of wing dams against the material to be moved. When the water pressure is removed the gate closes and the process of filling and "splashing" is repeated. It is by far the cheapest method of removing overburden, and the small initial expense and amount of water required make it available where a hydraulic plant would be impossible. Three such dams were in operation on this creek during the summer of 1908.

HOOSIER CREEK.

On Hoosier Creek an hydraulic elevator was in operation a portion of the summer. About 2 miles of 22-inch pipe brought the water from the head of the creek to the elevator on claim 14 above. Here a 200-foot head operated a 12-inch elevator having a 16-foot lift (Pl. V, *B*) and requiring about 17.5 second-feet of water for operating. Definite information is not at hand concerning the details of this plant, but it seemed to be in successful operation when the supply of water was adequate.

BAKER CREEK GROUP.

GENERAL CONDITIONS.

The mines on the south side of the divide in the Rampart district are all comparatively shallow, as in the Minook and Birch Creek regions. "Open-cut" methods are followed, and the auriferous

gravels are shoveled into the sluice boxes after the ground has been stripped by water. The benches on Pioneer and Thanksgiving creeks are the principal producers, but considerable preparatory work has been done on Eureka, Omega, Glen, and Sullivan creeks. The Baker Creek mines are less favorably situated than those of the Minook Creek group, owing to their southern exposure which allows the long hot days of spring to rapidly destroy the winter accumulation of ice and snow. They are also located on smaller streams and nearer the headwaters than most of the mines in the Rampart district.

In 1907 Frank G. Manley, of Baker Hot Springs, completed a number of small ditches to convey water for mining the bench gravels on Pioneer and Thanksgiving creeks. Several small ditches have been completed on Eureka, Glen, Gold Run, and Sullivan creeks. Owing to the scarcity of water, however, little work was accomplished during the past summer, except stripping ground to get mining property in shape for shoveling in.

WHAT CHEER BAR DITCH.

What Cheer Bar ditch taps Pioneer Creek near its headwaters, and carries water along the right bank for use on the benches along Pioneer Creek. The ditch is about 4 miles long, 5 feet wide, and has a grade of 5 feet to the mile. The water is used for ground stripping and for washing the gravels that are shoveled into the sluice boxes. For discharge measurements of this ditch, see page 79.

EUREKA CKEEK.

During 1908 Jerome Chute built a small ditch to operate on Eureka Creek above Pioneer Creek. Mr. Chute planned to make, during the winter of 1908–9, a thorough investigation of the possibilities of artesian wells on Eureka Creek.

THANKSGIVING DITCH.

Thanksgiving ditch taps New York and California creeks about one-half mile above their confluence and carries water to mining ground on Thanksgiving Creek. The ditch is 4 miles long, 5 feet wide, and has a grade of $6\frac{2}{3}$ feet to the mile. The water is used for ground stripping and for washing gravels shoveled into the sluice boxes. (See Pl. VII, *B*.) For discharge measurements of this ditch, see page 76.

SULLIVAN CREEK DITCH.

During the early part of the season of 1908 about 1 mile of ditch, having a capacity of approximately 10 second-feet, was constructed. This ditch is used to convey water for "open-cut" work in Tufty Gulch near the mouth. Several other small ditches were under construction.

WATER POWER FOR ELECTRIC TRANSMISSION.

Throughout the entire Yukon-Tanana region mining in general has been carried on by means of the meager water supply from individual creeks and with very little consideration for methods of economy. Fortunately most of the ground that has been worked has been wonderfully rich, and the miner has been able to follow haphazard methods and still obtain a substantial profit. But the camps already demand a greater water supply than the local creeks can furnish, and in the near future the miner will have to work cheaper ground and will be forced to give the water-supply question most careful consideration.

The situation of the present mining camps does not favor procuring an outside water supply by gravity. The region is part of a semiarid belt having an annual precipitation of 10 to 18 inches, and the topography of the country is such that ditch lines from the larger drainage areas, to which it is necessary to look for a supply commensurate with any reasonable development, are not altogether practical. Most of the larger streams are too far away or at too low an elevation to be used on the auriferous gravels.

Pumping seems to offer the most feasible solution of the problem, and the question naturally arises as to the best methods of developing power for this purpose. Steam and water are the only ones worthy of consideration; but the cost of wood for steam power is at present excessive and is constantly increasing, and unless[a] coal is discovered at a place convenient for transmitting electricity to the mines through a central steam plant the development of water power for electric transmission to pumping plants seems more practical. This method of utilizing the water supply would dispense with many miles of ditch construction and would not only furnish the camp with water, but also with power for running the hoist, elevating the tailings, draining the mines, lighting the underground work, pumping water to the sluice box, and in some localities for running the dredge.

The initial step in the location and development of a hydro-electric plant is the determination of daily flow and of the conditions affecting the flow of the stream or streams to be utilized. This is necessary in order to insure the maximum development of the low-water flow and to provide for storage or its equivalent, an auxiliary steam plant, for use during extreme drought. The collection of such data is a part of the work undertaken by the Geological Survey, and in connection with projects for water-power development attention is called to the records of Chatanika and Little Chena rivers and Washington Creek. (See pp. 23–48.) From these records the following table has been prepared.

[a] The coal deposits in the northern foothills of the Alaska Range south of Fairbanks may prove to be a valuable asset of the region. They are described by L. M. Prindle in Report on progress of investigations of mineral resources of Alaska in 1906: Bull. U. S. Geol. Survey No. 314, 1906, pp. 221–226.

This table gives the horsepower (80 per cent efficiency) per foot of fall that may be developed at different rates of discharge and shows the number of days on which the discharge and the corresponding horsepower were respectively less than the amounts given in the columns for "discharge" and "horsepower."

Estimated discharge and horsepower table for Chatanika and Little Chena rivers, 1907–1908; Washington Creek, 1908.

Discharge (second-feet).	Horsepower, 80 per cent efficiency per foot fall.	Days of deficient discharge.						
		Chatanika River near Faith Creek.		Chatanika River below Poker Creek.		Little Chena River and tributaries.		Washington Creek below Aggie Creek.
		June 16–Sept. 30, 1907.	July 13–Sept. 30, 1908.	1907.	1908.	July 22–Sept. 10, 1907.	May 1–Aug. 27, 1908.	May 5–Sept. 4, 1908.
22	2	.....	.....	.....	.....	.....	.....	0
28	2.5	.....	.....	.....	.....	.....	.....	3
33	3	0	.....	.....	.....	.....	.....	30
44	4	13	.....	.....	.....	.....	.....	51
55	5	19	.....	.....	.....	.....	0	61
66	6	30	.....	.....	.....	0	26	66
77	7	40	.....	.....	.....	3	31	68
88	8	48	2	.....	.....	7	36	72
99	9	56	4	.....	.....	13	44	75
110	10	62	19	.....	.....	15	48	76
132	12	69	37	.....	.....	23	55	.....
154	14	74	57	0	.....	35	58	.....
176	16	78	58	5	0	42	60	.....
198	18	79	65	17	5	45	63	.....
220	20	83	66	27	27	48	67	.....

It is evident from the above table that a certain amount of storage is necessary for economic development. (See tables on p. 102.) On Chatanika one storage would benefit two developments, the combined minimum power of which would be at least 5,000 horsepower. This could be used for pumping the ample supply at the mines (see p. 87) to an elevation sufficient for mining on the producing creeks tributary to the Chatanika and also for supplying other substations on Fairbanks and Goldstream creeks.

The situation of several other streams in the Yukon-Tanana regions (see table, p. 89) seems to offer opportunities for the development of electric power for transmission to the mining camps, but unfortunately no records have been kept of the flow of these streams, and their drainage areas are so undeveloped that it is very difficult to procure the desired information. The diagram in figure 3 shows considerable similarity in the run-off per square mile of drainage area of the streams for which records have been kept. This diagram and the accompanying table of drainage areas were specially prepared to guide the prospector or investor to the localities most favorable for power development.

In the judgment of those who have observed the stream conditions in the Yukon-Tanana region for several years the run-off reached its lowest point in the season of 1908. The records obtained this year may therefore be considered especially conservative, and it seems probable that they would afford a safe basis for estimates of supplies available for ditch or other water-power development.

STORAGE AND CONSERVATION.

In the Yukon-Tanana region, where for six months in the year the streams are closed by ice and where, except for a surface thaw of 1 to 3 feet during the summer months, the ground is frozen throughout the year from surface to bed rock—10, 20, 30, and in many places more than 200 feet below—it is considered more practical to use the daily flow of a stream during the open season than to attempt to conserve any excessive run-off; but the two-years' records indicate that commercial development of the region will necessitate the adoption of some means of conservation.

During the low-water period, which invariably occurs in July and August, the inadequacy of the water supply of the local creeks forces many operators to discontinue work and the rest to resort to various schemes to provide water for sluicing. The method most commonly practiced—that of returning water to the sluice boxes for a second and even a third use—not only entails extra expense but furnishes an inferior quality of water for sluicing, as the large amount of silt which the water carries so increases its transporting powers that its efficiency in saving the lighter gold is greatly curtailed.

Obviously these difficulties can be overcome only by obtaining an outside supply of water either by pumping or by gravity. The problem of furnishing a supply adequate for the needs of the camps during the open season would seem less difficult if storage could be provided for the run-off incident to the spring break-up. The computed discharge of streams in the Fairbanks district during the months of May and June and the diagram on page 85 give evidence that at this time of year water is abundant. As April and May are months of exceptionally slight precipitation—perhaps the smallest of all the year—the water must come from the melting of the snow and ice accumulated throughout the winter months.

In the spring of 1908 water began to run in the mining creeks and the more open country from the 20th to the 25th of April, and by the 1st of May the larger streams were breaking up. If the resulting run-off of 3 to 5 second-feet per square mile during May and part of June could have been distributed throughout July and August, a supply adequate for any reasonable development would have been at hand. If some practical plan for storing this excessive run-off could

be suggested a number of projected developments in this region might be considered as commercial possibilities.

The amounts of storage that would have been necessary to maintain discharges of 75, 100, and 125 second-feet in a ditch diverting water from Chatanika River near Faith Creek and to maintain discharges of 28, 33, and 55 second-feet in a ditch on Washington Creek near Aggie Creek are given in the following tables, together with the number of days of deficient flow for the different ditch capacities:

Storage table for Chatanika River near Faith Creek.

1907.

Capacity of ditch (second-feet.	Days of deficient flow.	Net storage required.	
		Second-feet for 1 day.	Acre-feet.
75	39	794	1,575
100	54	1,985	3,937
125	63	3,424	6,792

1908.

75	0	0	0
100	4	46	91
125	20	508	1,008

Storage table for Washington Creek below Aggie Creek.

1908.

Capacity of ditch (second-feet).	Days of deficient flow.	Net storage required.	
		Second-feet for 1 day.	Acre-feet.
28	3	7	14
33	30	125	248
55	61	1,247	2,473

The table for Chatanika River is based on records covering the periods from June 16 to September 30, 1907, and July 13 to September 30, 1908. Storage provided at the head of the Chatanika might be used in connection with power development near Poker Creek, where the river has a fall of 100 feet in 8 miles. The minimum flow of 167 second-feet for five days in 1907 and of 192 second-feet for two days in 1908 indicates a possible development of at least 1,500 horsepower. The table for Washington Creek covers a period from May 5 to September 4, and undoubtedly represents a minimum condition. During this time there were days when the discharge of the streams exceeded the capacity of the proposed ditches. Had storage reservoirs been provided this excess of flow

could have been conserved for use during a later low-water period. But the topographic maps of this section show no natural reservoirs which could be used for storage purposes and indicate that, except near the headwaters of the Chatanika, the country is not adapted to artificial reservoirs. Even if natural conditions were more favorable, the high price for labor,[a] the frozen ground, and the great depth to bed rock would make the construction of large dams nearly impossible. For these reasons it seems desirable to seek other means of storage.

Contrary to the general impression, more or less water flows in nearly all streams of the Yukon-Tanana region during the entire winter. While traveling over this section of country in April, 1908, the writer noticed that large "winter glaciers" had invariably been formed where the channels of small streams had become clogged and dammed, ice 12, 15, or even 20 feet thick being a not uncommon sight. Following the line of least resistance, the water flows around and over the obstructions, freezes, and remains until the summer heat melts it—as late as the 1st of July in sheltered spots. It occurred to the writer that some artificial method might be devised to bring about the formation of "winter glaciers" at the heads of streams proposed for development and that such a system would be of great value. Such artificial "winter glaciers," if protected from the sun by moss and brush, could be drawn upon for additional water supply during the low-water period. The method seems particularly applicable to most of the creeks on which records were kept. At the headwaters the creek bottoms are usually covered with a thick coat of willows, which would aid not only in the formation of the "winter glacier," but also in its protection. The matter seems worth considering, and the experiment would certainly be comparatively inexpensive.

Present conditions not only indicate the need of artificial storage, but emphasize the necessity of protecting the natural storage agents—the forests and the prevailing moss covering. Many years of growth have produced but a scanty supply of timber of inferior grade and size, and even casual observation makes it evident that, once destroyed, the forests can not be replaced in hundreds of years. Yet in many a camp the timber is being unnecessarily destroyed, apparently without any regard for the future.

It is admitted that the natural development of the country demands the use of the available timber supply, but there can be no excuse for such indiscriminate burning of extensive timbered areas as has occurred in the prospecting stages in most of the camps. Besides destroying more timber than would supply all legitimate demands, these fires ruin the heavy moss, which is the one great storage agent

[a] Five dollars per day and board for ordinary labor; mechanics, $7 to $8 per day and board.

of this region. In some localities this moss has been so badly burned that it no longer protects the frozen muck and ground ice from the summer sun, and the water is liberated so rapidly that the open season has hardly begun when the supply is practically exhausted. As a result a comparatively short period of no precipitation causes a water famine which might have been delayed had the moss remained to distribute the run-off in a more uniform manner and over a longer period. It was noted last spring that the streams first to start and quickest to discharge the storage from the accumulated snow were those in areas where the timber had been removed from the watershed. The operators throughout the district generally concede that on the producing creeks the floods are greater, their duration shorter, and the low-water period lower and longer than when work was first started.

The necessity for use of the timber supply is conceded, but it is evident that the future welfare of this country, as of older and more developed countries, demands the preservation of its forests because of their own especial uses and their influence on the development and conservation of other natural resources.

INDEX.

A.

Page.

Acknowledgments to those aiding 9
Acre-foot, definition of 10
Aggie Creek at—
  mouth:
    description 48
    discharge 48
    discharge, daily 48, 86
    gage heights 48
Albert Creek—
  discharge 56
Allen Creek—
  description 73–74
  discharge 74
Applegate Creek—
  discharge 83

B.

Baker Creek—
  description 73
  discharge 73
Baker Creek, North Fork—
  discharge 83
Baker Creek basin, description of 72–73
  stream-flow data in 73–84
  water power in 97–98
Bear Creek—
  description 30
  discharge 30
Beaver Creek—
  discharge 51
Beaver Creek basin, description of 49–50
  stream-flow data in 50–51
Belle Creek—
  discharge 41
Birch Creek at—
  Fourteenmile House:
    description 53
    discharge 53, 87, 89
    discharge, daily 53–54, 86
    gage heights 53–54
Birch Creek (North Fork)—
  description 54–55
  discharge 55
Birch Creek basin, description of 53
  stream-flow data in 53–59
  water power in 95–96
Boston Creek—
  discharge 41
Boulder Creek—
  description 58
  discharge 59
Brigham Creek—
  discharge 51
Bryan Creek—
  discharge 51
Buckeye Creek—
  discharge 72

C.

Page.

Cache Creek—
  discharge 84
California Creek at—
  Thanksgiving ditch:
    description 75
    discharge 75
    discharge, daily 75
    gage heights 75
California Creek branch ditch near—
  intake:
    description 77
    discharge 77, 88
    discharge, daily 77–78, 86
    gage heights 77–78
Caribou Creek—
  discharge 40
Chapman Creek—
  description 64
  discharge 64
Charity Creek—
  discharge 38
Chatanika River near—
  Faith Creek:
    description 33
    discharge 33, 87, 89
    discharge, daily 34, 86
    gage heights 34
    storage 102
  Murphy Creek:
    discharge 41
  Poker Creek:
    description 34
    discharge 35, 87, 89
    discharge, daily 35–36, 86
    gage heights 35–36
Chatanika River basin, description of 32–33
  discharge of 15, 87
    chart showing 17
  ditch building in 93
  water power in 96, 100
Circle district, description of 51–52
  gaging stations in 52
    location of, plate showing 52
  hydraulic development in 95–96
  stream-flow data in 53–59, 86, 88
    figure showing 85
Cleary Creek—
  description 40
  discharge 40
  mining on, view of 40
Climate, description of 14
Conservation, methods of 101–104
Cooperation, acknowledgments for 9
Crooked Creek (of Birch)—
  description 56
  discharge 56
Crooked Creek (of Chatanika)—
  discharge 41

Page.

Covert, C. C., work of 8
Current meters, use of 11–12

D.

Data. *See* Stream-flow data.
Deadwood Creek—
description 59
discharge 59
Definitions of terms used 9–11
Ditch construction, difficulties in 7, 90–92
methods of 90–91, 92
progress in 90
Dome Creek—
description 41
Drainage, description of 13–14

E.

Eagle Creek—
discharge 55
hydraulicking on, view of 94
water power 95
Eldorado Creek—
description 40–41
Elephant Gulch—
discharge 83
Electric transmission, possibilities of 99, 101
Elliott Creek near—
Sorrels Creek:
description 25
discharge 25, 87
discharge, daily 26, 86
gage heights 26
Ellsworth, C. E., work of 8
Equivalents, table of 10
Eureka Creek—
description 78
discharge 78
water power 98

F.

Fairbanks Creek—
description 30
discharge 30
Fairbanks district, description of 19–20
gaging stations in 20–21
location of, plate showing 20
hydraulic development in 93–94
mining in 92–93
stream-flow data in 22–51, 86, 88
figure showing 85
water power in 94
Faith Creek—
description 38
discharge 38
discharge, daily 38, 86
ditch from 93–94, 95
Fiftymile River at—
White Horse:
description 84
discharge 84
Fires, damage from 103–104
Fish Creek at or near—
Fairbanks Creek:
description 27–28
discharge 28, 87
discharge, daily 28, 86
gage heights 28

Page.

Fish Creek at or near—Continued.
mouth:
description 29
discharge 29
discharge, daily 29, 86
gage heights 29
Flat Creek—
discharge 41
Floats, use of 11
Fossil Creek—
discharge 51
Fox Creek—
description 44
Frozen ground, water from melting of 15–16

G.

Gage heights, readings of 12
Gassaway, A. D., on flow of Chatanika River 15
Goff Creek—
discharge 83
Gold, discovery and development of 12–13
Goldstream Creek at—
Claim 6:
description 43
discharge 43
discharge, daily 43–44
gage heights 43–44
Goldstream Creek basin, description of 42–43
stream-flow data in 43–44
Goose Creek—
discharge 72
Grand Central River, gaging on, view of 10
Granite Creek—
description 64
discharge 64

H.

Harrison Creek—
description 55
Henshaw, F. F., on ditch construction 90–91, 92
Hoosier Creek—
description 65
discharge 65, 69, 88
discharge, daily 66, 86
gage heights 66
hydraulic elevator on, view of 94
water power on 97
Hope Creek—
discharge 38
Hunter Creek—
description 68
discharge 68, 88
discharge, daily 68, 86
gage heights 68
water power on 97
Hutlinana Creek—
description 80–81
discharge 81, 83, 88, 89
discharge, daily 82, 86
gage heights 82
Hydraulic developments, details of 90–101
progress of 8

I.

Independence creek—
discharge 57

K.

Kokomo Creek— Page.
description 39
discharge 39
discharge, daily 39, 86
gage heights 39

L.

Little Chena River near—
Elliot Creek:
description 23
discharge 23, 87, 89
discharge, daily 24, 86
gage heights 24
Fish Creek:
description 24
discharge 24, 89
discharge, daily 25, 86
gage heights 25
Little Chena River basin, description of 22–23
discharge of 87
chart showing 17
stream flow data in 23–32
water power in 94, 100
Little Minook Creek—
description 66–67, 69
discharge 67, 88
discharge, daily 67, 86
gage heights 67
splash dam on, view of 96
water power 97
Little Minook Junior Creek—
description 66
discharge 66
Little Poker Creek—
discharge 40
Location of area 12–15
map showing 13

M.

Mackay Creek—
discharge 41
McManus Creek—
description 36–37
discharge 37
discharge, daily 37, 86
ditch from 93–94, 95
Mammoth Creek at—
Miller House:
description 56
discharge 57, 87
discharge, daily 57, 86
gage heights 57
Mastodon Creek—
discharge 57
Methods. *See* Stream measurement.
Miller Creek (of Little Chena River)—
description 30
discharge 31, 32
discharge, daily 31, 86
gage heights 31
Miller Creek (of Mammoth Creek)—
discharge 57
Miller Fork—
discharge 55
Miner's inch, definition of 10
Minook Creek near—
Chapman Creek:
discharge 69
Minook Creek near—Continued.
Little Minook Creek: Page.
description 63
discharge 63, 88, 89
discharge, daily 63–64, 86
gage heights 63–64
Minook Creek basin, description of 62–63
stream-flow data in 63–69
water power in 96–97
Moose Creek—
discharge 72
Moss, injury to, by fire 104
water stored by 16, 103
Murphy Creek—
discharge 41

N.

New York Creek—
Thanksgiving ditch:
description 74
discharge 74, 83, 87
discharge, daily 74–75, 86
gage heights 74–75
Nome Creek—
discharge 51

O.

Ohio Creek—
discharge 83
Ophir Creek—
discharge 51

P.

Patterson Creek basin, description of 83
stream-flow data in 84
Pedro Creek—
description 44
Pioneer Creek—
description 79
discharge 79, 88
discharge, daily 79–80, 86
gage heights 79–80
Poker Creek—
description 39
discharge 39
water power from 94
Pool Creek—
discharge 37
Porcupine Creek near—
Bonanza Creek:
description 57–58
discharge 58, 88
discharge, daily 58, 86
gage heights 58
water power 95–96
Power, electric transmission of 99–101
Price meter, description of 11
view of 10
Prindle, L. M., on climate and vegetation 14
Ptarmigan Fork—
discharge 55
Pumping, power for 99–100

Q.

Quail Creek—
discharge 71
Quartz Creek (of Crooked Creek)—
discharge 56
Quartz Creek (of Patterson Creek)—
discharge 84

R.

Page.

Rainfall, records of 14, 16–19
Rampart district, description of 59–61
gaging stations in 61–62
location of, map showing 60
stream-flow data in 62–84, 86, 88
figures showing 85
water power in 96–98
Roads, construction of 15
Ruby Creek—
description 65
discharge 65
Run-off, definition of 9
Russian Creek—
description 71
discharge 71

S.

Second-foot, definition of 9
Slate Creek—
description 65
discharge 65
Smith Creek—
discharge 37
Sorrels Creek—
description 26
discharge 27, 87
discharge, daily 27, 86
gage heights 27
Sourdough Creek—
discharge 41
Squaw Creek—
description 71
discharge 71
Starvation Creek—
discharge 72
Storage, possibilities of 101–104
Stream-flow data, explanation of 9–11
value of 7
Stream measurement, methods of 11–12
Sullivan Creek—
discharge 84
water power 98

T.

Tanana River, description of 19
Temperature, range of 14–15
Thanksgiving ditch near—
outlet:
description 76
discharge 76, 83, 88
discharge, daily 76–77
gage heights 76–77
shoveling in on, view of 96
water power 98

Page.

Timber, destruction of 103–10
Tolovana River, West Fork—
discharge 72
Tolovana River basin, description of 71–72
stream-flow data in 72
Trail Creek—
discharge 51
Transportation, means of 14–15, 60–61
Troublesome Creek near—
Quail Creek:
description 70
discharge 70, 71, 88
discharge, daily 70, 86
gage heights 70
Troublesome Creek basin, description of 69–70
stream-flow data in 70–71
Twelvemile Creek—
discharge 55

V.

Vegetation, description of 14, 20, 51–52, 60
Velocity, measurement of 11–12

W.

Washington Creek near—
Aggie Creek:
description 45, 46–47
discharge 45, 47, 89
discharge, daily 45, 47, 86
gage heights 45, 47
storage 102
Washington Creek basin, description of 45
discharge of 87
stream-flow data in 45–48
water power in 94, 100
Water power, details of 90–98
transmission of 99–101
Water supply, conditions of 15
What Cheer Bar ditch—
discharge 83
water power 98
Winter glaciers, water from, melting of 15, 103
Wolverine Creek—
discharge 83
Woodchopper Creek—
discharge 84

Y.

Yukon basin, stream-flow data in 71
Yukon Tanana region, description of 12–15
location of, map showing 13
water of 15–19
See also particular districts.

O

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

WATER-SUPPLY PAPER 229

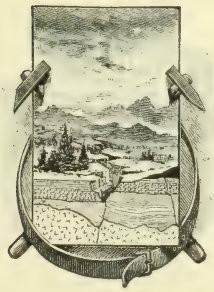
THE DISINFECTION OF SEWAGE AND SEWAGE FILTER EFFLUENTS

WITH A CHAPTER ON THE

PUTRESCIBILITY AND STABILITY OF SEWAGE EFFLUENTS

BY

EARLE BERNARD PHELPS



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CONTENTS.

	Page.
Disinfection of sewage and sewage-filter effluents	7
Introduction	7
Sewage purification	7
Purifying agents	7
Fate of bacteria in sewage filtration	8
Necessity for disinfection	12
Methods of disinfection	15
Classification of methods	15
Heat	15
Lime	16
Acids	16
Ozone	17
Chlorine and its compounds	17
Germicidal action	17
Chlorine gas	17
Hypochlorites	18
Use in disinfection	18
Hamburg experiments	19
Berlin experiments	21
Experiments at Bengal, India	24
Experiments in Ohio	25
Electrolytic chlorine processes	25
Electrolytic manufacture of chlorine	25
Webster process	26
Woolf process—Electrozone	27
Hermite process	27
Oxychloride process	28
Copper and its compounds	29
Miscellaneous methods	32
Permanganates	32
"Amines" process	32
Sodium benzoate and other organic compounds	33
Summary of disinfection methods	33
Experimental investigations	34
History	34
Bacteriologic methods and expression of results	35
Investigations at Boston	37
Scope and character of experiments	37
Preliminary experiments with chloride of lime	38
Disinfection of trickling-filter effluent	39
Disinfection of crude sewage	46
Disinfection of septic sewage at Red Bank, N. J	51
Disinfection of trickling-filter effluent at Baltimore, Md	56
Comparative germicidal efficiencies of chlorine and some of its compounds	60
Effect of calcium hypochlorite on colon and typhoid bacilli	62

Page.

Disinfection of sewage and sewage-filter effluents—Continued.
Practical applications and costs of disinfection 63
Conclusion 70
Putrescibility and stability of sewage-filter effluents 74
Introduction 74
Putrescibility 75
Relative stability 77
Definitions 77
Estimation of reducing time 78
Theoretical relation between reducing time and relative stability 80
Determination 83
Incubation periods 83
Effect of temperature on reducing time 86
Summary of method 87
Interpretation of results 88

DISINFECTION TABLES.

TABLE 1. Bacteria in sewage and in effluents of sewage filters at Boston in 1904. 11
2. Bacteria in sewage, septic effluent, and trickling-filter effluents at Boston in 1906 11
3. Disinfection of three crude hospital sewages with chloride of lime 20
4. Disinfection of the crude screened sewage of Eppendorfer, Germany, by chloride of lime 21
5. Disinfection of crude Berlin sewage with chloride of lime 22
6. Destruction by chloride of lime of *B. coli* embedded in gelatine 23
7. Disinfection of septic sewage by chloride of lime at Bengal, India 25
8. Disinfection of effluents with chloride of lime at Lancaster and Marion, Ohio 25
9. Analyses of London sewage before and after treatment by the Webster process 26
10. Summary of Rideal's experiments on the use of oxychloride at Guilford, England 28
11. Disinfection of trickling-filter effluents with copper sulphate at Columbus, Ohio 29
12. Disinfection of sewage and effluents with copper sulphate at Columbus, Ohio 30
13. Effect of organic matter and of alkalinity on the germicidal properties of copper sulphate 31
14. Disinfection of trickling-filter effluent with copper sulphate at Boston 31
15. Disinfection of effluents with copper sulphate in Ohio 32
16. Chemical analysis of trickling-filter effluent at Boston before and after disinfection with chloride of lime and sedimentation 40
17. Disinfection of trickling-filter effluent with chloride of lime at Boston; weekly averages 42
18. Disinfection of trickling-filter effluent at Boston; summary of bacteriological results averaged by periods to show the effect of changes in temperature and in the amount of available chlorine 43
19. Relation between individual tests of bacterial removal and the average result at Boston 44

Page.

TABLE 20. Relation between individual bacterial counts and the average result at Boston 44
21. Relation between time of contact and efficiency of disinfection with chloride of lime 45
22. Disinfection of crude sewage with chloride of lime at Boston; series 1 and 2 48
23. Disinfection of crude sewage with chloride of lime at Boston; series 3. 49
24. Disinfection of crude sewage with chloride of lime at Boston; summary of results 50
25. Disinfection of septic sewage with chloride of lime at Red Bank, N. J.; weekly averages 54
26. Relation between individual tests of bacterial removal and the average result at Red Bank, N. J 55
27. Chemical analyses of trickling-filter effluent at Baltimore, before and after disinfection with chloride of lime and sedimentation ... 57
28. Disinfection of trickling-filter effluent with chloride of lime at Baltimore; weekly averages 58
29. Relation between individual tests of bacterial removal and the average result at Baltimore 58
30. Relation between individual bacterial counts and the average result at Baltimore 59
31. Average bacterial removal during the disinfection of trickling-filter effluent at Baltimore 59
32. Relative germicidal properties of chlorine and some of its compounds 60
33. Comparative resistance to calcium hypochlorite of *B. typhi* and *B. coli* in aqueous emulsion 63
34. Estimates of the cost of maintenance and operation of a plant for disinfecting sewage or effluent with chloride of lime; based on a capacity of 5,000,000 gallons a day 66

RELATIVE STABILITY TABLES.

TABLE 1. Relation between reducing time and relative stability at 20° centigrade 82
2. Summary of stability tests of trickling-filter effluents, showing time required to exhaust the available oxygen 84
3. Comparison of relative stability results obtained from the twenty-day incubation period shown in Table 2 with those calculated from a four-day period 85
4. Comparison of relative stability results obtained from smaller numbers of samples by the use of four, six, and twenty day incubation periods 85
5. Relation between relative stability and reducing time at 20° and at 37° centigrade 87

ILLUSTRATION.

PLATE I. Plan of sewage-disposal works at Red Bank, N. J 52

THE DISINFECTION OF SEWAGE AND SEWAGE FILTER EFFLUENTS.

By Earle Bernard Phelps.

INTRODUCTION.

The investigations on which this report is based were conducted by E. B. Phelps at the sanitary research laboratory and sewage experiment station of the Massachusetts Institute of Technology at Boston, Mass., and, in collaboration with Mr. Phelps, by Francis E. Daniels at the sewage-disposal works at Red Bank, N. J., and by Ezra B. Whitman at the Walbrook Testing Plant at Baltimore, Md., under cooperative agreements with the Massachusetts Institute of Technology, the State Sewerage Commission of New Jersey, and the city Sewerage Commission of Baltimore.

SEWAGE PURIFICATION.

PURIFYING AGENTS.

The essential agents of sewage purification are provided and employed by nature. The slow action of the soil bacteria, aided by atmospheric oxygen, eventually converts into harmless mineral ingredients all organic matter that comes within its sphere of activity, the process being analogous to that of combustion. Sewage purification as practiced to-day is but the intensive application of these natural processes under controllable conditions. The improvements that have been made in methods of treating sewage have not involved the discovery or application of new principles, but have merely increased the working efficiency of the natural bacterial agencies. The constant aim of the experimenters has been to increase the rate at which sewage can be treated on a given area of land. From the old-time sewage irrigation field, with its maximum capacity of possibly 10,000 gallons an acre in twenty-four hours, to the present-day trickling filter capable of dealing with two or three million gallons an acre a day, the march of improvement has been steady and continuous. The amount of sewage that can be purified

on an acre of filtering area has been increased two or three hundred fold, and investigators are working toward a still greater increase.

It must be admitted that the significance of the word "purify" has also undergone a radical change. The effluents are no longer pure ground water. The liquid flowing from a modern trickling filter looks to the untrained eye like the original sewage. The organic matter of the sewage is no longer "burned up" to harmless mineral matter; indeed, there is almost as much organic matter in the effluent as in the raw sewage, and sometimes more. What change then has taken place to justify the use of the term "purified?" The answer lies in the fact that the organic matter has been changed but not removed. To carry out the simile, the organic matter, though not burned, has been charred or partly oxidized, and this charring process has been sufficient to rob it of its putrescibility or foulness. In other words, its chemical composition has been so altered that it is no longer capable of undergoing rapid putrefactive decomposition.

On first consideration it appears inconceivable that the chief object of sewage disposal—prevention of the fouling of streams—could be attained by such subtle changes in the nature of the organic matter. Nevertheless, effluents containing comparatively large amounts of organic matter may be discharged into streams without fear of causing nuisances if the organic matter is nonputrescible and if conditions preclude immediate sedimentation. The work of purification proceeds in the stream as it does in the soil until the oxidation, or combustion, is complete, oxygen for that purpose being sufficiently abundant in a reasonably clean stream. On the other hand, too much crude sewage added to water first robs it of all its available oxygen, then, in the anaërobic condition thus established, kills the beneficent oxidizing bacteria and transforms the stream practically to an open sewer. It is apparent, therefore, that purification of sewage has come to mean primarily the removal of its tendency to putrefy and not the total oxidation and removal of all its organic matter.

FATE OF BACTERIA IN SEWAGE FILTRATION.

In the older and more perfect methods of sewage purification the bacteria of the sewage with the other organic matter were destroyed by the straining action of the soil and the oxidizing action of the normal soil bacteria; but a modern filter of coarse stones neither strains the material nor affords opportunity for vigorous oxidation. Much of the original organic matter passes through such a filter, having undergone changes so slight as almost to defy detection by ordinary chemical means. It is reasonable, therefore, to inquire as to the fate of the sewage bacteria and particularly as to the pathogens, or disease-producing microbes. The data on this point are somewhat

conflicting. The question was raised in 1893 in connection with the first septic tank at Exeter, England. The fear was expressed that pathogenic germs might even multiply in the tank, as other forms of bacteria are known to do. Sims Woodhead conducted an investigation as a result of which he concluded that no organisms capable of setting up morbid changes in animals after inoculation came from the tank. Pickard introduced an emulsion of typhoid bacilli into the Exeter tank and observed a slow diminution in number. It is important to note, however, that even after fourteen days 1 per cent of the original number was still alive. Pickard also reported a removal of over 90 per cent of the typhoid organisms introduced into a contact filter. Rideal, on examining the effluents of three Scott-Moncrieff filters at Caterham, England, found reductions in *Bacillus coli* ranging from 95 per cent to 98.5 per cent. He made the following statement before the Royal Sewage Commission:[a] "Satisfactory evidence in most of the systems is now available from which I think we are justified in concluding that even if towns on a river like the Thames adopted bacterial schemes the pathogenicity of the London water supply would not be adversely affected thereby."

On the other hand, there is some evidence that the pathogenic properties of sewage are not materially altered in its passage through a coarse-grained filter. Alfred MacConkey[b] made a series of tests upon the longevity of *B. typhi* in various waters. Samples of the liquid under examination were inoculated with large numbers of typhoid bacilli and were kept under observation. In one experiment the organism was isolated from sewage thirteen days after inoculation. In a second set of two tests it was not found after fifteen and after seventeen days. In two contact-bed effluents it was found after fifteen and seventeen days, respectively, while in two other contact-bed effluents it did not survive beyond the sixth day. MacConkey concluded that the numbers of typhoid organisms reaching a filter are ordinarily so small that there is but slight possibility of their passing through, but "if from any cause they arrive to the tanks in such large numbers as the *B. coli*, then certainly they might appear in the effluent just as the *B. coli* does." In interpreting such results due allowance must be made for the fact that the isolation and identification of the typhoid bacillus under such conditions is extremely difficult and that failure to detect the organism carries much less experimental weight than a positive result.

Houston,[c] in a careful investigation of the subject for the Royal Sewage Commission, found that the effluents from septic tanks, contact beds, and trickling-filter beds contained enormous numbers of

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[a] Interim Rept. Royal Sewage Commission, 1901, Question No. 4148, p. 251.

[b] Second Rept. Royal Sewage Commission, 1902, p. 62.

[c] Houston, A. C., Second Rept. Royal Sewage Commission, 1902, p. 26.

bacteria. In some of the tests the per cent reduction in the effluents as compared with the raw sewage was striking; but as it was necessary to judge an effluent by its actual condition, and as the number of micro organisms still remaining was almost always very large, he concluded that per cent purification is of minor importance. In not a few of the tests the bacteria were practically as numerous in the effluent as in the raw sewage. The relative abundance of the different kinds of bacteria appeared to be much the same in the effluents as in the crude sewage. Of undesirable bacteria, such as *B. coli*, proteus-like germs, spores of *B. enteritidis sporogenes*, and streptococci, the effluents contained nearly as many as the crude sewage. The reduction in numbers of these objectionable bacteria was apparently not marked enough to be of consequence from the point of view of the epidemiologist. No definite proof was found that the effluents from bacterial beds were conspicuously safer than crude sewage in their possible relation to disease. Attention was especially called to the presence of streptococci in the effluent. Houston contends that if it be true that streptococci are more delicate germs than the typhoid bacillus, their presence in large numbers in the effluent indicates the possibility or probability that the typhoid bacillus also survives under similar conditions—a view that leads to the inference that the biological processes at work are not strongly inimical, if hostile at all, to the vitality of pathogenic germs. Experiments with *B. sporogenes*, a spore-forming organism, have shown that it passes through filters in almost undiminished numbers.

Besides the facts already mentioned, little information is available which bears directly on the fate of the pathogens, and particularly of the typhoid organism, in sewage purification. It is therefore necessary to examine the available indirect evidence. By studying the removal of certain specific organisms that are easily detected and certain well-defined groups of organisms existing in sewage, the probability of the elimination of the typhoid organism can be determined. In the absence of further data it must be assumed for the sake of safety that the elimination of the typhoid bacillus is not materially greater than that of the other species and groups that may be studied. During the summer of 1904 there were operated at the sewage experiment station four septic tanks running at storage periods of from twelve to forty-eight hours, nine contact beds differing in material, depth, and rate, three trickling filters, and three sand filters, one of each set being run with crude sewage and two kinds of septic effluents, respectively. The results of bacterial counts are shown in Table 1, in which the numbers are averages of all results obtained with one kind of filter.[a]

[a] Winslow, C.-E. A., The number of bacteria in sewage and sewage effluents: Jour. Infect. Dis., vol. 1, Suppl. 1, 1905, p. 209.

TABLE 1.—*Bacteria in sewage and in effluents of sewage filters at Boston in 1904.*

[Winslow.]

Source of sample.	Number of examinations.	Bacteria per cubic centimeter.					
		Lactose gelatin at 20° C.			Lactose agar at 37° C.		Anaërobic agar.
		Liquefiers.	Acid formers.	Total.	Acid formers.	Total.	
Sewage	56	365,000	1,670,000	5,430,000	1,670,000	3,760,000	2,440,000
Septic effluent	56	162,000	495,000	1,750,000	650,000	1,040,000	930,000
Contact filters	140	60,000	270,000	1,060,000	290,000	570,000	440,000
Trickling filters	18	134,000	114,000	451,000	284,000	1,170,000	200,000
Sand filters	15	500	1,360	9,160	11,400	43,600	1,200

The septic tank and two trickling filters in operation at the same station during the summer of 1906 gave the average results recorded in Table 2, showing that less than one-half of the bacteria growing at 37° C. were removed by filtration, and that the reduction in the number of colon bacilli was practically in the same proportion.

TABLE 2.—*Bacteria in sewage, septic effluent, and trickling-filter effluents at Boston in 1906.*

Source of sample.	Bacteria per cubic centimeter; lactose agar at 37° C.	B. coli; positive[a] tests in one-millionth of a cubic centimeter.
		Per cent.
Sewage	1,300,000	65
Trickling filter receiving sewage	750,000	35
Septic effluent	1,650,000	66
Trickling filter receiving septic effluent	750,000	35

[a] The bile broth presumptive test recommended by D. D. Jackson was employed.

Johnson,[a] in his experiments at Columbus, found a reduction in the total number of bacteria ranging from 33 per cent to 60 per cent in primary-contact filters, and a removal of about 39 per cent of the remainder in secondary-contact filters, and from 30 per cent to 80 per cent in trickling filters, depending largely on the depth of the filter. Subsequent sedimentation increased this removal to 87 per cent. Thumm and Pritzkow,[b] at Berlin, report a reduction in the number of bacteria from 17,000,000 in the sewage to 6,000,000 in the effluent of a double-contact filter. At La Madelein, France, Calmette[c] found 5,000,000 bacteria per cubic centimeter in crude sewage, 2,900,000 in a secondary-contact effluent, and 800,000 in the effluent from a trickling filter. The sewage contained 20,000, the contact effluent 4,000, and the trickling effluent 2,000 colon bacilli. At Plainfield, N. J., the

[a] Johnson, Geo. A., Report on sewage purification at Columbus, Ohio, 1905.

[b] Thumm, K., and Pritzkow, A., Mitteilungen aus der Königlichen Prüfungsanstalt für Wasserversorgung und Abwässerbeseitigung zu Berlin, 1903, vol. 2, p. 127.

[c] Calmette, A., Recherches sur l'epuvation des eaux d'égout, Lille, 1907, vol. 2.

double-contact filter was found to reduce the number of bacteria from an average of 1,000,000 per cubic centimeter to an average of 322,000: *B. coli* ranged from 1,000,000 to 100,000 in the sewage and from 100,000 to 10,000 in the effluent.[a] An experiment performed by Houston[b] is important in this connection: *B. pyocyaneus*, a pathogenic organism, was applied to the top of a trickling filter, and ten minutes later the bacillus appeared in the effluent, continuing to be discharged for ten days. In a similar manner the same organism was found to pass through a septic tank and a contact filter successively, and to persist in both for nine days. At Baltimore, Md., the board of advisory engineers concluded that 95 per cent of the bacteria in the sewage could be removed by a system comprising a septic tank, 9-foot trickling filters, and supplementary sedimentation basins.[c] Such results are better than those usually obtained elsewhere, and if they can be maintained in practice they will go far toward solving the problem in that locality.

From a consideration of the available evidence it may be stated in a general way that coarse-grained, rapid sewage filters remove a considerable proportion of the sewage bacteria; that such removal has not been found to be sufficiently complete in practice to have great sanitary significance; that bacteria of various groups and certain specific organisms pass through such filters in practically the same proportions as the bacteria as a whole; and that, in the absence of any information to the contrary, it should be assumed that such filters have no greater effect on the typhoid and other pathogenic organisms than on *B. coli*, *B. pyocyaneus*, sewage streptococci, or the different groups of sewage bacteria.

THE NECESSITY FOR DISINFECTION.

It is probable that removal of bacteria will again be considered an essential factor in sewage purification. That it was so considered formerly is well known. The development of the modern rapid filter has made it possible to introduce sewage purification under conditions where it would have been impossible or prohibitively expensive in former days. In the acceptance of a partial solution of the problem much has been gained and but little lost. The process of purification that renders practically stable the offensive organic matter of sewage has accomplished the most important and in many cases the only essential requirement. If, however, sewage effluents find their way into the drinking waters of neighboring communities, the question of the relative responsibility of the settlements is debatable. It is generally conceded at present that efficient sewage purification should be

[a] Rept. Sewerage Commission of New Jersey for 1906.

[b] Houston, A. C., Fourth Interim Rept. Royal Sewage Commission, 1904, vol. 3, p. 77.

[c] Report of the Board of Advisory Engineers to the Sewerage Commission of Baltimore, 1906.

undertaken by the communities in which the sewage originates, and that purification of the water supply is the urgent duty of the other communities. As streams flowing through populous districts are necessarily contaminated and unfit for domestic use without filtration, it is considered unjust to require a community to purify its sewage to a higher degree bacterially than that shown by the stream into which it is discharged. On the other hand, in the fight against infectious diseases, sound tactics demand an attack on the enemy as near as possible to the initial source of infection. The best and easiest place to destroy typhoid germs is at the bedside of the typhoid patient; but this method can not be relied on to keep sewage free from infection, and the next strategic point is certainly the sewage. Once at large the germs may reach their victims in a score of well-known ways, and who will say by how many devious and unknown paths? With increasing knowledge of these facts and with improved processes and reduced cost of disinfection it is not too much to expect that the disinfection of sewage will some day be regarded as an integral part of its purification and as a necessary measure of protection for the community.

One of the ways by which typhoid germs pass from the sewer to the victim is by means of shellfish fed or fattened in polluted water, and many of the oyster and clam beds of the eastern seaboard are subject to pollution by sewage. In England conditions are so serious that the demand for shellfish has perceptibly decreased. The situation presents obvious difficulties. The water of a polluted river may be rendered potable through filtration, but the purification of shellfish seems to be out of the question; it follows, therefore, that health must be safeguarded either by preventing the discharge of the bacteria of sewage on shellfish beds or by prohibiting the taking of the shellfish. In a large community where the shellfish industry is small it will probably be more satisfactory to adopt the latter method, but in small communities whose sewage pollutes large and important beds thorough bacterial purification is not an unreasonable requirement. Unfortunately the greatest shellfish areas of the country are situated near large cities, where they are subject directly or indirectly to possible pollution from sewage discharge.

In a carefully prepared paper on the pollution of shellfish beds, G. W. Fuller[a] states that the annual crop of oysters gathered along the Atlantic and Gulf coasts in 1902 amounted to more than 25,000,000 bushels, exceeding in value $13,000,000, and that the crop of clams was more than 2,000,000 bushels, valued at $2,000,000. Over one-half of this total production came from New Jersey, Maryland, and Virginia, and the shellfish were grown mainly in the

[a] Concerning sewage disposal from the standpoint of the pollution of oysters and other shellfish, with especial reference to their transmission of typhoid fever: Jour. Franklin Inst., vol. 160, 1905, p. 82.

waters of Delaware and Chesapeake bays, which receive the sewage from many large cities. At present this sewage is so enormously diluted by the bay waters that the danger of pollution is in most places remote, but it is present and ever increasing.

In Baltimore a system of sewerage and sewage disposal is being planned to remedy the already serious pollution of Patapsco River. In calling on a commission of experts for advice the sewerage commission of Baltimore specified "that the effluent proposed to be discharged into Chesapeake Bay or its tributaries in the system to be recommended by the engineers shall be of the highest practicable degree of purity." [a]

By agreement between the States of New Jersey and Pennsylvania the condition of Delaware River has been thoroughly investigated, and the pollution of that stream by sewage from Trenton, Bordentown, and other smaller communities in New Jersey, and Philadelphia, Easton, and other Pennsylvania cities, is prohibited after certain specified dates.[b] The necessity for protecting these valuable shellfish beds makes bacterial removal an essential feature in any scheme of sewage disposal which may be considered for such places.

The board of advisory engineers at Baltimore recommended that the settled trickling-filter effluent be given a final treatment on sand filters. The cost of works for the complete treatment of 75,000,000 gallons of sewage a day by septic tanks, trickling filters, sedimentation basins, and sand filters was estimated at $3,283,250, of which sum $1,040,750, or over 31 per cent, was for supplementary treatment. The annual cost of operation is expected to be $115,500, of which $55,000, or 48 per cent, is for supplementary treatment. This gives some idea of the cost of complete bacterial removal by filtration processes over and above the cost of reasonable organic purification. In regard to disinfection by chemical means the advisory engineers state: "To remove all bacteria remaining in the settled effluent from the sprinkling filters by disinfectants, such as hypochlorite of lime or of sodium or sulphate of copper, would be prohibitively expensive"—an authoritative opinion based on the best evidence then to be had. Almost no American data on chemical disinfection were available, and the results of experiments in Germany indicated that such disinfection could be accomplished only at high cost. The patented processes mainly used in England were also expensive. It was therefore desirable to learn just how effective disinfection processes could be made under conditions in America—how much they would cost, and what after effects, objectionable or otherwise, might follow their introduction.

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[a] Report of the Board of Advisory Engineers to the Sewerage Commission of Baltimore, 1906.

[b] Rept. New Jersey State Sewerage Commission, 1907.

A review of the available data and a short experimental investigation made in 1906 at Boston[a] led the writer to believe that there is much value in the process and that it might afford the best possible solution of the whole problem under certain conditions common in this country, particularly in localities where the shellfish question is involved.

METHODS OF DISINFECTION.

CLASSIFICATION OF METHODS.

In Great Britain the somewhat indefinite allusions of the royal sewage commission to sterilization as a finishing process in sewage treatment aroused a storm of discussion that resulted, at least, in clearing away many misconceptions. Sterilization processes of many kinds have been investigated, and the subject has been freely discussed. For the following classification of sterilizing agents and for many of the facts noted here the writer is indebted to Rideal,[b] whose carefully prepared paper on the subject discusses its possibilities in a thoroughly impartial manner. Other authorities are cited wherever possible. Except when otherwise stated, costs are based on current prices in eastern markets.

The different methods and substances proposed for the sterilization of effluents are considered in the following order:

1. Heat.
2. Lime.
3. Acids.
4. Ozone.
5. Chlorine and its compounds.
   - (*a*) Chlorine gas.
   - (*b*) Hypochlorites, or oxychlorides.
   - (*c*) Electrolytic chlorine processes.
6. Copper and its compounds.
7. Miscellaneous.
   - (*a*) Permanganates.
   - (*b*) "Amines" process.
   - (*c*) Sodium benzoate and other organic compounds.

HEAT.

The use of heat has been suggested for disinfecting sewage. In his testimony before the royal sewage commission E. E. Klein[c] referred to a patented process which he considered practicable, by the use of which sufficient ammonia could be recovered from the sewage nearly to pay for the treatment; but there is no record that this process

[a] Phelps, Earle B., and Carpenter, William T., The sterilization of sewage-filter effluents: Tech. Quart., vol. 19, 1906, p. 382; Contributions from the Sanitary Research Laboratory, vol. 4, 1908.

[b] Rideal, S., On the sterilization of effluents: Jour. Royal Sanitary Institute, vol. 26, p. 378.

[c] Interim Rept. Royal Sewage Commission, 1901, question 9674, p. 519.

has ever been used on a working scale. A device for heat interchange similar to that employed in the Forbes sterilizer may possibly, as is claimed, raise water to the boiling point and cool it again within 5° F. of the initial temperature. With coal at $3 per ton having a calorific value of 10,000 British thermal units, the fuel cost alone of such an operation would be about $7 per million gallons of sewage. The ammonia in a million gallons of Boston sewage, if in the form of sulphate, would have a market value of $20. Whether the difference between the value of the ammonium sulphate and the cost of the fuel is sufficient to cover the cost of operation, including labor, evaporation of the dilute solution, and all fixed charges can be determined only by actual experiment, but the plan is not wholly without possibilities.

LIME.

Caustic lime acts only slightly as a germicide, and the considerable removal of bacteria that takes place when lime is used as a precipitant in sewage is undoubtedly due to the action of the precipitate itself in dragging down with it the bacteria which it has entangled. Such action occurs to some extent in the precipitation of any substance, and even the sedimentation of sewage is always accompanied by reduction in the numbers of bacteria. Lime alone, therefore, would be of little value for sterilizing effluents. Rideal states that 60 to 70 grains per imperial gallon (860 to 1,000 parts per million) are inefficient in sterilization. Thresh, however, believes that lime would produce a satisfactory sterilization of effluents.[a]

ACIDS.

Most bacteria, and particularly typhoid and cholera germs, are more readily destroyed by acids than by alkalies. Rideal, therefore, considers it feasible to employ acids as germicides. He states that Stutzer found 0.05 per cent acid solutions fatal to bacteria in twenty-four hours; that Ivanoff found that 0.04 per cent to 0.08 per cent of acid destroyed the cholera germs in the sewage of Berlin and of Potsdam; that Kitasato found 0.08 per cent of sulphuric acid fatal to typhoid bacilli in fifteen minutes, and that he had himself obtained similar results. To furnish 1,000,000 gallons of sewage with 0.08 per cent of sulphuric acid requires 6,650 pounds of acid, costing approximately $73. Smaller amounts of acid might be used, as it would be unnecessary to kill typhoid germs in so short a time as fifteen minutes; but, on the other hand, most sewage contains a considerable amount of free alkali which must be neutralized before any germicidal effect of

[a] Interim Rept. Royal Sewage Commission, 1901, question 8917, p. 502.

the acid would be obtained. This process consequently would seem to be impracticable except in emergencies. It is interesting to note that the sewage of Worcester, Mass., contains normally an average of 0.01 per cent of free sulphuric acid, or half enough to kill cholera germs in twenty-four hours.

OZONE.

Ozone has been used more or less successfully in Germany, particularly at Weisbaden, for sterilizing drinking water. Though the process has been most favorably commented on by those in immediate charge of the investigations, it has not been generally regarded as successful. The possibility of procuring a satisfactory effluent by this process, when the water is that of a highly-polluted river is beyond question, but whether the process can satisfactorily treat a sewage effluent of considerable turbidity has not been determined. Rideal calls attention to the fact that ozone is but sparingly soluble in water, and on that account it might fail to penetrate the solid masses in the effluent, since the rate at which a dissolved gas will penetrate solids in a liquid is a direct function of its solubility. The principal cause of failure of the ozone process, however, seems to be its expense. If this be true in waterworks it is hardly possible that such treatment could be applied to sewage effluents as an additional safeguard after purification. Data are not at hand for estimating the cost of applying ozone treatment to sewage effluents, but besides the cost of operation there is the very considerable cost of installing the necessary machinery and towers.

CHLORINE AND ITS COMPOUNDS.

GERMICIDAL ACTION.

Chlorine is well known as a powerful germicide. As a bleaching agent it acts on organic coloring matter indirectly by means of the free nascent oxygen which it liberates from the water in which it is dissolved, and it is probable that its germicidal action is similar. In other words, chlorine and ozone owe their germicidal power to the same thing—nascent oxygen. Chlorine, however, has the advantages of being cheap, of being more readily soluble, and of being obtainable in compounds that are easily transported and handled.

CHLORINE GAS.

Until within a few years chlorine has been manufactured commercially by the Weldon or some similar process. In the Weldon process hydrochloric acid is made to react with a complex mixture of man-

ganese hydroxide and lime—"Weldon mud"—the reaction being essentially

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2,$$

though in reality it is much more complex. Recently, however, electrolytic processes have been developed, by which the cost of manufacture has been materially reduced, particularly where cheap water power is available. Chlorine prepared by the mixing of common salt, an acid, and a suitable oxidizing agent was used in England as early as 1800 by Cruikshank, who recommended manganese dioxide and potassium bichromate as oxidizing agents. The objections to the use of gaseous chlorine are chiefly the cost of transportation, the difficulty and danger of handling the gas, and the difficulty of measuring accurately the amount of gas added to the effluent. Furthermore, in disinfection free chlorine is not so efficient as the hypochlorite.

Available chlorine, a term frequently used in the discussion of chlorine disinfection methods, is determined by titrating a solution with arsenious acid, or with some other reducing agent, and it represents in reality the oxidizing power of the substance expressed in terms of chlorine. For example, hypochlorous acid in the presence of a reducing agent is decomposed according to the following equation:

$$HClO = HCl + O.$$

The oxidizing power of this acid, or the available chlorine, is, therefore, two hydrogen equivalents per molecule, which is twice its total chlorine content, a fact that makes the term available chlorine a misnomer, but it has come into general use in the chlorine industries and it is a convenient expression. In this article it signifies oxidizing power, determined against arsenious acid, and expressed in terms of chlorine.

HYPOCHLORITES.

Use in disinfection.—Chlorine is handled commercially in the form of bleaching powder, or chloride of lime—an impure product composed largely of calcium hypochlorite. Bleaching powder or "bleach" containing from 35 per cent to 40 per cent of available chlorine can be obtained in the market. The hypochlorite dissolves in water, leaving a residue composed chiefly of calcium hydrate and calcium carbonate. Hypochlorites in general are made by adding chlorine to caustic alkalies. Bleaching powder is made by passing dry chlorine gas over freshly-slaked lime. It is manufactured in this country in large amounts, the chlorine being obtained by the electrolysis of salt. Abroad the chlorine is made by the older methods, and much

foreign bleach is sold in this country in competition with the electrolytic product. "Eau de Javelle" and "Labarraque's solution" are solutions of sodium hypochlorite. "Chloros," a commercial preparation of sodium hypochlorite, contains 10 per cent by weight of available chlorine.

Hypochlorites have long been recognized as powerful and efficient disinfectants. The sodium and potassium compounds have not been generally used on a large scale because of their relatively high cost and the difficulty of preparing and keeping them in the dry state, but calcium hypochlorite has been extensively employed. The first Royal Sewage Commission of Great Britain used it in deodorizing London sewage in 1854.[a] The committee of 1885 of the American Public Health Association found it to be the best disinfectant available, cost and efficiency considered. It was used by Dibdin[b] in 1884 to deodorize the sewage of London, but it was not successful for that purpose and was later abandoned in favor of sodium permanganate. Its action on specific bacteria was studied by Nissen[c] in 1890. The use of bleaching powder as a sewage disinfectant has been more extensively studied in Germany than elsewhere. At the Hygienic Institute of Hamburg investigations have been made by Proskauer and Elsner, Dunbar and Zirn, Dunbar and Korn, Schumacher, and Schwarz. At the Royal Testing Station in Berlin, Kranepuhl and O. Kurpjuweit have each reported investigations.

Hamburg experiments.—Proskauer and Elsner[d] experimented at Hamburg with sewage which had been clarified by the Rothe-Degener system. They obtained satisfactory disinfection with chloride of lime, using concentrations of chlorine ranging from 2.7 to 4.0 parts per million, and ten minutes exposure sufficed practically to eliminate *B. coli.* Dunbar and Zirn[d] treated crude sewage and, in common with later workers, they imposed much more exacting standards of disinfection and used much greater concentrations of chlorine. After having employed cholera germs as test organisms, they concluded that the satisfactory disinfection of crude Hamburg sewage would require 25 parts per million of available chlorine and an exposure of two hours. Dunbar and Korn[e] studied the disinfection of crude sewage with special reference to its subsequent purification on biological filters. Schumacher[f] investigated the problem of disinfecting hospital sewages that had not received any previous treatment. In a

[a] Second Rept. Royal Sewage Commission, London, 1861.
[b] Dibdin, W. J., Jour. Assoc. Eng. Soc., vol. 40, 1908, p. 310.
[c] Zeit. Hyg., vol. 8, 1890, p. 62.
[d] Vierteljahrsschr. ger. Med., vol. 16, 1898, Suppl. Heft.
[e] Ges. Ing., vol. 27, 1904.
[f] Idem, 1905.

preliminary set of bottle experiments he obtained the following results with the sewages of three hospitals.

TABLE 3.—*Disinfection of three crude hospital sewages with chloride of lime.*

[Schumacher.]

Concentration of chloride of lime.	Hours of contact.	Bacteria per cubic centimeter.		
		Initial content: 23,000,000.	Initial content: 37,000,000.	Initial content: 21,000,000.
		After treatment.	After treatment.	After treatment.
1:7,000	2	540	200	8,400
	4	140	260	100
	6	200	100	20
	24	160	20	60
1:5,000	2	60	60	100
	4	160	40	800
	6	120	.....	600
	24	30	.....	.....
1:2,000	2	80	420	40
	4	20	.....	60
	6	20	20	20
1:1,000	2	60	20	80
	4	120	40	180
	6	40	40	.....

The amount of available chlorine in the chloride of lime used in these experiments is not stated, but it was probably not far from 30 per cent. On that assumption the concentration of available chlorine in the four sets of tests would be 43, 60, 150, and 300 parts per million, respectively. The high initial numbers indicate a very strong sewage. It is also worthy of note that the reduction in the number of bacteria with only 43 parts of chlorine is much greater than would be demanded in ordinary practice. Disinfection on a large scale was also conducted by the same investigator at two hospitals. After a storage period of two hours samples of one liter each were tested for *B. coli*. With a concentration of 1:2,000, or about 150 parts per million of available chlorine, *B. coli* was isolated from a liter of water in only 6 samples out of 43, not being found in 88 per cent of the samples tested. With chloride of lime in the proportion of 1:5,000, or about 60 parts per million of available chlorine, *B. coli* was destroyed in 62 per cent of the samples in two hours and in 64 per cent of the samples in four hours. Schwarz [a] called attention to the fact that excessive amounts of disinfectant are necessary on account of the large floating particles, a point previously commented on by Schumacher. Schwarz proposed, therefore, that all sewage should be carefully screened before disinfection in order to remove particles exceeding three millimeters in diameter. The screening of hospital sewage should be even more complete, removing particles exceeding one millimeter in diameter.

[a] Ges. Ing., vol. 29, 1906, p. 773.

During experiments at the Eppendorfer purification works, a sewage flow of about 60,000 United States gallons a day was available, and a tank holding about four hours' flow was used. As information was especially desired regarding the effect of the treatment on the cholera vibrio, an emulsion of another vibrio (Leuchtvibrionen) was added to the sewage at a regular rate before treatment, after it had been determined that this test organism would not only pass through the tank but would persist for days in the filters. Table 4 summarizes the results.

TABLE 4.—*Disinfection of the crude screened sewage of Eppendorfer, Germany, with chloride of lime.*

[Schwarz.]

Concentration of chloride of lime.[a]	Tests for vibrio in 1 cubic centimeter amounts.		Test for B. coli in 1 cubic centimeter amounts.		Final number of bacteria per cubic centimeter.[b]
	Total number of tests.	Number of positive tests.	Total number of tests.	Number of positive tests.	
1:2,000			17	0	15
1:5,000	51	0	51	1	23
1:10,000	28	0	7	0	36
1:20,000	15	0	6	0	72
1:30,000	10	0			3,620
1:40,000	8	4			59,000
Control					950,000

[a] 1:10,000 is about 30 parts per million of available chlorine, assuming that the chloride of lime contained 30 per cent of available chlorine.
[b] Initial number of bacteria per cubic centimeter, 1,350,000.

It was noted that a concentration of chloride of lime of 1:2,000 materially affected the subsequent treatment of the disinfected sewage in trickling filters. Oxygen consumed and ammonia in the effluent were higher and nitrates lower than normal. An interesting fact noted was the production of chlorates in the filter, over 10 parts per million being recorded at one time. Schwarz concluded that sewage can be satisfactorily disinfected with chloride of lime after having been carefully passed through one millimeter mesh screens. One part in 5,000 (60 parts per million of available chlorine) was considered necessary for the destruction of typhoid germs and from one part in 7,000 to one part in 10,000 (30 to 40 parts of available chlorine) for cholera vibrio. The disinfected sewage can be subsequently purified without previous neutralization of the disinfectant.

Berlin experiments.—At the royal testing station in Berlin the subject of sewage disinfection has been studied by Kranepuhl[a] and by Kurpjuweit.[b] Kranepuhl undertook to determine the concentration of chloride of lime and the time of contact necessary to destroy the colon bacilli in crude Berlin sewage. These bacilli numbered

[a] Mitteilungen aus der Königlichen Prüfungsanstalt für Wasserversorgung und Abwässerbeseitigung zu Berlin, vol. 9, 1907, p. 149.
[b] Idem, p. 162.

about 100,000 per cubic centimeter. They were considered an index of the pathogenicity of the sewage, because they are more numerous and more resistant than the pathogenic forms. The bleaching powder employed contained available chlorine ranging from 25 to 35 per cent. One liter samples of sewage were treated with the desired amounts of chloride of lime, and at the expiration of the specified time the remaining available chlorine was determined and was then neutralized with sterile sodium thiosulphate. Nutrient broth was then added to the entire liter sample, after which the sample was incubated. *B. coli* was sought in the incubated sample by the usual means, and confirmatory tests for it were made.

Kranepuhl's results are summarized in Table 5, in which positive tests mean that *B. coli* was found in 1 liter.

TABLE 5.—*Disinfection of crude Berlin sewage with chloride of lime.*

[Kranepuhl.]

Available chlorine (in parts per million.)	Time of exposure.	B. coli in liter samples.		
		Number of samples tested.	Number of positive tests.	Per cent of positive tests.
	Hours.			
50	2	20	11	55
50	4	9	2	22
60	2	17	6	35
60	4	6	3	50
150	2	19	4	21
150	4	10	1	10
300	2	16	1	6
300	4	7	0	0

Kurpjuweit[a] studied the penetration of solid particles by the disinfectant. He made test cubes of gelatine having a volume of about 10 cubic centimeters, which he immersed in solutions of chloride of lime for definite times, then removed and melted in warm water, after which he determined the available chlorine. He found the amount of available chlorine to be a regular function of the time of exposure and of the concentration of the solution. The most striking fact noted was the small quantity of chlorine actually absorbed. For instance, a cube that had been immersed for ninety hours gave a mean concentration of chlorine within its own volume equal to but 1 per cent of the concentration of the solution. There was also shown to be a chemical combination between the chlorine and the gelatine. In order to determine whether such chlorine was active in disinfection before it became combined, similar gelatine cubes, inoculated with *B. coli* before setting, were immersed for two hours in solutions containing from 60 to 3,000 parts per million of available chlorine. The results in Table 6 were obtained.

[a] Loc. cit.

TABLE 6.—*Destruction by chloride of lime of B. coli embedded in gelatine.*

[Kurpjuweit.]

Concentration of solution (average available chlorine in parts per million).	Number of B. coli remaining in 10 cubic centimeters after 2 hours.
0 (control)	91,500
60	55,400
150	43,500
300	48,100
300	6,600

The value of these results in practical work is problematic for several reasons. The cubes employed are much larger than the particles that should be in any sewage to be disinfected, and the character of the material is still more significant, because cubes of solid gelatine do not represent in any way the porous, semisoluble masses that occur in sewage. The question of penetration is an important one, and there can be no doubt that the practical efficiency of disinfection processes is limited by the ability of the disinfectant to penetrate small, solid particles that may be in the sewage. This point has been illustrated in a practical manner by Kurpjuweit's experiments. Four samples of crude sewage were screened through sieves having openings 2, 5, 7, and 10 millimeters in diameter, respectively. Four portions of each of the filtrates thus obtained were then treated with chloride of lime, so proportioned that the available chlorine was 150, 300, 600, and 3,000 parts per million, respectively. In the sewage that was screened through a 2-millimeter mesh, 150 parts per million of available chlorine destroyed all the *B. coli* in four separate liter samples, while the same concentration of chlorine destroyed the *B. coli* in only 5 out of 8 liter samples screened through the 10-millimeter mesh. Indeed, 3,000 parts of available chlorine were required to remove completely the *B. coli* in the samples screened through the 10-millimeter mesh.

It should be noted that the investigators at Hamburg and at Berlin dealt wholly with crude sewage. Even when purification plants are in operation the disinfection is invariably applied first. No good reason for this procedure is obvious, unless it is that preliminary sedimentation tanks are available and supplementary tanks are not. In Germany the method of operation is possibly justified by the fact that the processes are being studied in order that they may be adopted for temporary use during epidemics, and it is not proposed to practice disinfection regularly. The expense of treating crude sewage, however, is at least twice that of treating a well-purified filter effluent. The very high standards that have been established for this work are

also of interest. It is proposed so to treat a sewage containing over 100,000 *B. coli* per cubic centimeter that the number of that kind of bacillus will be reduced to less than one in a liter. The result can hardly be expressed in per cent purification, and it is proper to inquire why such severe standards are employed. If the number of colon bacilli were reduced even to one per cubic centimeter, it would mean a reduction of 99.999 per cent. It may safely be inferred that the number of typhoid and cholera germs would be reduced in about the same ratio, and furthermore that the number of typhoid and cholera cases due to the discharge of this sewage would be similarly decreased. In other words, if such disinfection were generally adopted, 99,999 cases of disease out of every 100,000, which are due, directly or indirectly, to sewage pollution, would be eliminated. Such reduction would seem to be very satisfactory, and yet it is proposed to improve this a thousand fold by insisting on an elimination of the colon bacilli from 1-liter samples, thus making the cost so great that it practically prohibits the use of the process, except for short periods during serious epidemics. It is well worth considering whether a continuous removal of 99 per cent of the disease germs is not a better safeguard of the public health than an occasional complete removal during epidemics.

Experiments at Bengal, India.—The government of Bengal,[a] in 1904, appointed a commission to report on the pollution of Hooghly River by the effluents of septic tanks. Though the commission decided that the physical and chemical pollution of the river by the effluents was improbable, as sufficient dilution took place at all seasons to prevent any nuisance, bacterial purification of the effluents was deemed advisable. Experimental sand filters and copper sulphate disinfection satisfactorily removed the germs, but substitution of chloride of lime for the copper salt accomplished the same result at much less expense.

A septic tank installed near Calcutta was connected with a public latrine serving about 2,000 persons. From 400 gallons to 2,500 gallons of septic-tank effluent were daily treated with various amounts of chloride of lime, the available chlorine in which ranged from 20 to 60 parts per million. The numbers of bacteria initially present were not determined, but the final numbers are sufficiently low to indicate a satisfactory treatment. Furthermore, it was shown that increasing the concentration of the chlorine beyond a certain limit has very little effect on the residual bacteria. The results of this work are summarized in Table 7.

[a] Indian government resolution on the working of septic tanks. Calcutta, January 6, 1906.

TABLE 7.—*Disinfection of septic sewage by chloride of lime at Bengal, India.*

Available chlorine (in parts per million).	Number of tests.	Number of samples.	Bacteria remaining (average number per cubic centimeter).
20	9	31	33
30	7	24	10
40	8	28	48
60	7	25	52

Experiments in Ohio.—In 1907 the Ohio State Board of Health studied the disinfection of sewage effluents in cooperation with the Bureau of Plant Industry of the United States Department of Agriculture. The results, reported by Kellerman, Pratt, and Kimberly,[a] related in part to the use of chloride of lime. The average results of four series of tests made with this disinfectant are summarized in Table 8.

TABLE 8.—*Disinfection of effluents with chloride of lime at Lancaster and at Marion, Ohio.*

[Kellerman, Pratt, and Kimberly.]

Series.	Available chlorine (in parts per million).	Number of bacteria per cubic centimeter at 20° C.		Number of bacteria per cubic centimeter at 37° C.		Number of acid formers per cubic centimeter at 37° C.	
		Initial.	Final.	Initial.	Final.	Initial.	Final.
A	4.0	130,000	140	14,000	49	840	0
B	2.8	60,000	1,600	12,000	120	3,000	0
C	4.1	225,000	1,600	120,000	390	16,000	1
D	6.0	2,000,000	700,000	900,000	230,000	70,000	24,000

Each series represents a three-day test, during which 18 samples were examined in duplicate. Series A was made on the effluent of a sand filter at the Boys' Industrial School, Lancaster, and Series B, C, and D on the sand-filter effluent, contact-filter effluent, and septic-tank effluent, respectively, at Marion, Ohio. A subsequent study of the possibilities of treating the septic tank effluent at Marion led the authors to conclude that satisfactory disinfection could be accomplished by the use of sufficient bleaching powder to give 25 parts per million of available chlorine.

ELECTROLYTIC CHLORINE PROCESSES.

Electrolytic manufacture of chlorine.—When an electric current under a tension of not less than 2.5 volts is passed through a solution of common salt or of calcium or magnesium chloride, chlorine gas appears

[a] Kellerman, K. F., Pratt, R. W., and Kimberly, A. E., The disinfection of sewage effluents for the protection of public water supplies: Bull. 115, Bur. Plant Industry, U. S. Dept. Agr., 1907.

at one electrode and sodium hydroxide or the corresponding alkali at the other. In the electrolytic manufacture of chlorine the products of the dissociation are kept apart and are removed from the cell as quickly as possible, for if they are allowed to come together again they immediately unite and form a hypochlorite. This method of manufacturing hypochlorites has been employed in many of the so-called "electrolytic disinfection processes."

The Webster process.—One of the earliest electrolytic treatments was devised by Webster over twenty years ago, when, in 1889, he installed an experimental electrolytic plant at Crossness, England, to treat London sewage.[a] In his process crude sewage flowed between iron electrodes placed in long troughs, and an electric current was passed from one electrode to the other at a tension of only two volts and a current density of 0.9 ampere per square foot of electrode. It was estimated that the treatment of 1,000,000 gallons of crude sewage required the consumption of 240 pounds of iron and 450 kilowatt hours of electricity. Sedimentation followed the electrical treatment, and a large amount of material was removed. In fact the process was virtually one of chemical precipitation, the iron dissolved from the electrode being first converted into hypochlorite, or other salt, and then being decomposed by the alkali present and precipitated. The solution of iron at the positive pole allowed the electrolytic reaction to proceed at a lower voltage than that required to liberate free chlorine. The results shown in Table 9 are the averages of 20 analyses, and they indicate the degree of purification obtained by the Webster process.

TABLE 9.—*Analyses of London sewage before and after treatment by the Webster process.*

	Parts per million.	
	Initial.	Final.
Suspended solids	333.5	15.6
Nitrogen as free ammonia	43.4	32.2
Albuminoid ammonia	5.0	2.0
Oxygen consumed	12.4	5.2

Though the process was originally conducted as a chemical precipitation, credit is due Webster for first pointing out the disinfecting value of the hypochlorites that are formed. T. M. Drown,[b] commenting on the process, observed that the American Public Health Association recognized the value of hypochlorites as early as 1888, and that their electrolytic manufacture was nothing new. Nevertheless its application to sewage was new and gave promise of success.

[a] The Engineer, London, vol. 67, 1889, p. 261; also Eng. News, vol. 21, 1889, p. 338; vol. 22, 1889, p. 388.
[b] Jour. New England Waterworks Assoc., vol. 8, 1894, p. 135; also Eng. News, vol. 31, 1894, p. 236.

In a later paper before the British Medical Association[a] Webster called attention to the possibilities of electrolyzing sea water and thus laid the foundation for the many later processes that are based on that principle. A plant was later installed at Bradford, England, and in 1890 Doctor McLintock stated that 70 per cent of the putrescible organic matter of the sewage had been removed.[b]

Fermi,[c] after having investigated the process at the hygienic institute at Munich, concluded that the process is one of chemical precipitation and that it is more expensive than the lime process, and similar conclusions were reached by König and Remele.[d]

The Woolf process—Electrozone.—Woolf's process differed from Webster's in that strong brine was electrolyzed, and the resultant chlorine and caustic soda were allowed to recombine to form sodium hypochlorite. The hypochlorite solution was then added to the sewage or water to be treated. In the spring of 1893 a plant of this kind was installed under the direction of the health department of New York City for treating the sewage of about 31 dwellings at Brewster, N. Y.,[e] a village situated on a small stream, the waters of which discharge into Croton Lake. The experiment was considered so successful that the health department installed a similar plant at the same place to discharge hypochlorite solution into Tonnetta Creek.[f] Sixteen hundred pounds of salt per million gallons of sewage were used, and the plant required an electric current of 700 amperes at 5 volts tension. This seems to have been the first plant established for the specific purpose of destroying bacteria; before that time the removal of organic matter had been the aim. An electrozone plant installed at Maidenhead, England, in 1897, was examined by Rideal, Robinson, and Kanthack in 1898. The bactericidal action was marked and the effluent was found to contain but few bacteria; this plant was not, however, continued[g] in operation. At Havana, Cuba, the Woolf process was employed for preparing a disinfectant solution to be used for treating the streets and the harbor.

The Hermite process.—The Hermite system differs from the Woolf system only in minor details. In reports on the process great stress is laid on the presence of magnesium hypochlorite in the electrolyzed solution, and there is much evidence that magnesium hypochlorite, owing probably to its lesser stability, is a more active agent than other hypochlorites. In later years this same fact has been observed,

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[a] Eng. News, vol. 22, 1889, p. 388.
[b] Brit. Med. Jour., vol. 2, 1890, p. 498.
[c] Arch. f. Hyg., vol. 13, 1891, p. 207.
[d] Arch. f. Hyg., vol. 28, 1897, p. 185.
[e] Eng. News, vol. 30, 1893, p. 41.
[f] Eng. Record, vol. 29, 1894, p. 110; Elec. Eng., vol. 18, 1894, p. 101.
[g] Rideal, S., Sewage and its purification, 3d ed., New York, 1906, p. 185.

and it has been the basis of fanciful claims for patented processes, whose owners have invoked hypothetical oxides of chlorine to explain the results. A commission appointed by the London Lancet to investigate the Hermite process found that the solution obtained was similar to ordinary hypochlorite [a] in its chemical properties. A plant installed at Worthing, England, was investigated in 1894 by Kelly,[b] who reported that the hypochlorite solution contained from 0.22 to 0.75 gram per liter of available chlorine. The claim made for this solution —that mixed with equal parts of sewage it would instantly kill all germs—was not substantiated. A plant employing the Hermite process, established at Havre, France, in 1893, was investigated by a commission appointed by the imperial board of health of Germany and by one sent from Paris by the council of hygiene, and both bodies reported adversely. Other Hermite plants were installed at various places, but were finally abandoned. At Poplar, England, the Hermite solution is prepared on a large scale, and it is used for general disinfecting purposes as well as for street watering.

The oxychloride process.—The oxychloride process differs from the Hermite and Woolf processes only in matters of detail in the electrolytic cell. Greater efficiency than the older processes in the production of hypochlorites is claimed for it. At Guilford, England, Rideal made a test of the effect of oxychloride treatment on raw and septic sewages and on effluents of primary, secondary, and tertiary contact beds. The summary of his results given in Table 10 shows what was accomplished. The results, especially in respect to the removal of *B. coli*, are all that can be desired.

TABLE 10.—*Summary of Rideal's experiments on the use of oxychloride at Guilford, England.*

Source of sample.	Available chlorine parts per million.	Time of contact.	Number of organisms per cubic centimeter.					
			Total.		B. coli.		B. enteritidis.	
			Initial.	Final.	Initial.	Final less than—	Initial.	Final less than—
Sewage	30	4.3 hours	23,000,000	50,000	1,000,000	1.0	1,000	10.0
	50	do	23,000,000	20	1,000,000	.2	1,000	.2
	70	do	23,000,000	10	1,000,000	.2	1,000	.2
Septic effluent	25–44	1 to 4 hours	2,500,000–4,500,000	20–600	100,000–1,000,000	1.0–.2	10–1,000	1.0–.2
Effluent from first contact bed.	20	40 minutes			100,000	.2		
	20	2 hours					20–100	.2
Effluent from second contact bed	10.6		1,000,000–2,000,000	40	1,000,000	.2	10–1,000	.2
Effluent from third contact bed.	2.5	1 hour			1,000–10,000	.2		
	2.5	4.5 hours					10–100	1.0
	.5	0.5 hour			1,000–10,000	.2		
	.5	4.5 hours					10–100	0.2

[a] Lancet, vol. 1, 1894, p. 1321.

[b] Public Health, vol. 6, 1894, p. 261.

Examinations of the few organisms remaining in the sewages and effluents after treatment showed them to be largely organisms of the hay bacillus group—aerobic spore-forming bacteria which are probably beneficial in the further oxidation of the organic matter. Absolute sterilization required very high concentration of chlorine.

COPPER AND ITS COMPOUNDS.

Moore and Kellerman, in 1904, suggested that copper sulphate be used in water sterilization.[a] Since that time a great deal of experimental work has been done, mainly in connection with water. The more important experiments, with sewage will be outlined.

Johnson and Copeland[b] at Columbus, Ohio, in 1904, in their work with trickling filter effluents, obtained the results given in Table 11.

TABLE 11.—*Disinfection of trickling filter effluents with copper sulphate at Columbus, Ohio.*

[Johnson and Copeland.]

	Copper sulphate in parts per million.	Reduction in bacteria (per cent).	
		In 3 hours.	In 24 hours.
First series, average of 3 sets	5	90.0	99.9
	10	98.0	99.95
	20	98.5	99.96
Second series, average of 3 sets	10	40.0	99.7
	20	60.0	99.9
	40	88.0	99.95

They found the action of copper sulphate to be most rapid during the first hour. They estimate the cost for chemicals alone at $5 per million gallons of effluent treated with 10 parts per million of copper sulphate, and $10 if treated with 20 parts per million—an expense which they consider prohibitive.

The use of copper sulphate as a disinfectant was more thoroughly investigated by Johnson at Columbus in 1905.[c] Experiments were made with crude sewage, and with effluents from trickling, contact, and sand filters. The effect of temperature, of organic matter, and of alkalinity on the efficiency of the process were determined and special studies were also made to determine the effect of the treatment on colon and typhoid organisms. The principal results with the various sewages treated are summarized in Table 12.

[a] U. S. Dept. Agr., Bureau of Plant Industry, Bull. 64, 1904.

[b] Jour. Infect. Diseases, Suppl. No. 1, 1905, p. 327; also Reports and papers, Am. Pub. Health Assoc. vol. 30, pt. 2, p. 327.

[c] Report on sewage purification at Columbus, Ohio, 1905, p. 471; also Jour. New England Waterworks Assoc., 1905, p. 474.

TABLE 12.—*Results of disinfection of sewage and effluents with copper sulphate at Columbus, Ohio; total number of bacteria remaining after contact periods of one hour and of three hours.*[a]

[Johnson.]

Copper sulphate (in parts per million.)	Series A.	Series B.		Series C.		Series D.	
	1 hour.	1 hour.	3 hours.	1 hour.	3 hours.	1 hour.	3 hours.
1,000	3,000	1,000	240	430	60	2,100	280
200	.....	5,000	600	1,100	130	6,000	1,400
100	9,000	6,000	500	2,100	230	5,500	1,800
40	.....	3,400	700	1,200	230	6,500	1,300
20	14,000	11,000	1,900	3,500	600	13,000	2,600
10	.....	21,000	4,500	7,500	1,260	20,000	5,000

Bacteria per cc.

[a] Series A. Crude sewage; initial number..... 1,200,000
B. Effluent of sprinkling filter..... 1,000,000
C. Effluent of contact filter..... 400,000
D. Effluent of sand filter..... 280,000

Each series is the average of from three to five sets of tests.

Longer periods of contact up to twenty-four hours gave results of no additional significance, except that when the lower concentrations of copper were used the number of bacteria showed a decided increase after about the third hour, an indication that the copper was removed from solution, probably by combination either with the organic matter or with carbonic acid. Subsequent increase in number of bacteria is a phenomenon of frequent occurrence in disinfection work. It is in fact neither possible nor desirable to prevent perpetually the feeding of bacteria on the organic matter of the disinfected effluents. The significant fact in Johnson's tests is that the bacteria originally present were practically eliminated, and it may safely be assumed that under conditions existing in a stream there would be no multiplication of the typhoid or other pathogenic bacteria.

Two important facts were brought out in this study. The disinfection obtained with 100 parts per million of copper sulphate is, for practical purposes, but little better than that obtained with 10 parts, and results obtained in a one-hour contact are practically as good as those obtained in a three-hour contact. Johnson's work was done at summer temperature, and in order to determine the effect of temperature on the germicidal action parallel experiments were conducted at 5° and at 20° C. It was found in general that a result which could be obtained at the higher temperature in thirty minutes would be attained at the lower temperature in about three hours. This is a point that has usually been overlooked, and it is of special significance in practical operation, as effluents in the northern latitudes would have a temperature of about 5° C. during much of the year. It is interesting to note that temperature has little effect on the germicidal efficiency of hypochlorites.

The combined effect of organic matter and alkalinity was determined by treating the undiluted effluent and the same effluent after being diluted 1 to 1 and 1 to 2 with tap water. The effect was decidedly noticeable in the weaker concentrations of copper sulphate, and much less so where the concentrations of copper were excessive. The results with 10 parts of copper sulphate per million are summarized in Table 13.

TABLE 13.—*Effect of organic matter and of alkalinity on the germicidal properties of copper sulphate: per cent removal of bacteria at end of one hour's contact with 10 parts per million of copper sulphate.*

[Johnson.]

Source of sample.	Dilution.		
	0	1:1	1:2
Crude sewage	96.1	97.5	98.5
Trickling filter effluent	97.3	99.0	99.1
Sand filter effluent	70	86	91

The efficiency of copper sulphate as a disinfectant was investigated in 1906 at the Sanitary Research Laboratory of the Massachusetts Institute of Technology by treating the effluent from an 8-foot trickling filter. Table 14 gives the average results divided into two periods to show the effect of temperature of the effluent. At the conclusion of the tests a composite sample of the sediment drawn from the sedimentation tank during the experiment was analyzed. The copper contained in the sediment accounted very closely for the total amount of copper added, a fact that makes it apparent that little copper left the tank in soluble form.

TABLE 14.—*Disinfection of trickling filter effluent with copper sulphate at Boston, Mass.; average results.*

Period.	Copper sulphate (in parts per million).	Temperature.	Number of bacteria per cubic centimeter.			Number of B. coli[a] per cubic centimeter.		
			Initial.	Final.	Per cent removed.	Initial.	Final.	Per cent removed.
1906.		° F.						
October 13–31	4	56	230,000	14,000	94.0	44,000	640	98.5
November 3–19	4	46	250,000	51,000	80.0	48,000	770	98.4
November 21–December 10	8	43	240,000	5,000	97.9	32,000	390	98.8

[a] Jackson's bile media used.

The work of Kellerman, Pratt, and Kimberly in Ohio during the winter of 1906–7 consisted mainly of experiments with copper sulphate as a disinfectant. Their investigations, probably the most comprehensive ever made with copper sulphate, were conducted under actual working conditions and with several kinds of effluent. The

chemical composition of the water, particularly in regard to its hardening constituents, was found to exert an important influence on the results. Their original paper[a] on the subject contains complete chemical analyses of the effluents treated. Table 15, containing a brief summary of average results calculated from the original tables, shows in a general way what was accomplished. The authors concluded that copper sulphate is not so efficient as chlorine compounds, is more seriously affected by carbonates, and is much more expensive.

TABLE 15.—*Disinfection of effluents with copper sulphate in Ohio.*

[Kellerman, Pratt, and Kimberly.]

Series.	Copper sulphate (in parts per million.)	Number of bacteria per cubic centimeter at 20° C.		Number of bacteria per cubic centimeter at 37° C.		Number of acid formers per cubic centimeter.	
		Initial.	Final.	Initial.	Final.	Initial.	Final.
A	5	6,000,000	1,200,000	140,000	120,000	6,000	600
	6.7	250,000	70,000	19,000	10,000	6,000	900
	10	60,000	16,000	47,000	10,000	2,600	1,000
	13	65,000	23,000	37,000	5,500	4,600	600
	20	120,000	20,000	8,000	11,000	1,600	110
	29	60,000	3,900	24,000	6,000	1,200	10
	40	160,000	8,500	75,000	4,700	5,500	110
	67	200,000	34,000	81,000	14,000	7,000	700
B	7.3	110,000	23,000	12,000	1,800	600	48
	14	75,000	9,500	16,000	600	75	0
	22	55,000	7,000	5,500	200	75	0
C	6.5	390,000	110,000	170,000	41,000	8,000	3,000
	15	230,000	65,000	42,000	16,000	5,000	2,200
	40	29,000	6,000	30,000	8,500	5,500	750
	116	84,000	7,000	28,000	2,000	5,000	560

A. Effluent of contact filter at Westerville, Ohio.
B. Effluent of sand filter at Lancaster, Ohio.
C. Effluent of sand filter at Marion, Ohio.

MISCELLANEOUS METHODS.

PERMANGANATES.

Potassium permanganate and sodium permanganate have been used for the oxidation of organic matter in streams. At London when the Thames becomes extremely foul during low-water periods, sodium permanganate is added to its waters in order to destroy odors and putrescible material, but the treatment undoubtedly results in partly sterilizing the water. It is claimed that the germicidal action is not sufficiently great to interfere with the normal oxidizing changes in the stream. The use of permanganates has been proposed for rendering effluents of chemical precipitation plants nonputrescible.

"AMINES" PROCESS.

The so-called "amines" process was developed by H. Wollheim in England. It is claimed that trimethylamine treated with lime or other alkali produces a very poisonous substance. Herring brine is

[a] Kellerman, K. T., Pratt, R. W., and Kimberly, A. E.: The disinfection of sewage effluents for the protection of public water supplies, Bull. 115, Bur. Plant Industry, U. S. Dept. Agr. 1907.

used to supply the amine. A large excess of lime is added and the mixture is used to precipitate crude sewage. Klein made a test of the process at West Horn in 1889, and found that a clear, nonputrescent, sterile effluent could be obtained. Similar results were obtained at Wimbledon,[a] where 768,000 bacteria per cubic centimeter in the sewage were completely removed. The sludge is also nonputrescible. The process does not seem to have been further developed.

SODIUM BENZOATE AND OTHER ORGANIC COMPOUNDS.

Sodium benzoate is supposed to possess powerful germicidal properties, and its use as a disinfectant for sewage was suggested to the writer. It would apparently have the distinct advantage over such other disinfectants as chlorine and copper salts of not combining with organic matter, thus rendering all the disinfectant added available for a long time. Sodium benzoate was applied regularly to a trickling filter effluent at Boston during March and April, 1907. An addition of commercial benzoate at the rate of 0.8 part per million for twenty-six days gave an average reduction of total bacteria from 140,000 to 54,000 per cubic centimeter, or a 62 per cent removal. Doubling the amount of benzoate increased the efficiency somewhat, the average reduction then being from 370,000 to 84,000 per cubic centimeter, or 78 per cent. The cost of benzoate for the treatment is $1 per million gallons for 0.8 part and $2 for twice that quantity. Obviously this substance is not an efficient disinfectant in sewage work.

Other organic substances, such as the phenols and the coal-tar products, were suggested, but in general their high cost eliminates them from consideration. The possibility of after effects must also be considered. There is a certain advantage in the use of a substance which is itself used up in the reaction or which is converted into harmless compounds. On the other hand, the organic disinfectants are extremely powerful and there is always a chance of the discovery of some new compound with the requisite germicidal properties and the low cost that will make it the ideal sewage disinfectant.

SUMMARY OF DISINFECTION METHODS.

Two of the methods of disinfection that have been mentioned appear not to have been sufficiently investigated, namely, disinfection by heat and by organic compounds. The heat method holds a reasonable possibility that sufficient ammonia may be recovered to pay for the necessary heating, but actual trial is essential for convincing proof. A systematic study of organic compounds as disinfectants has yet to be made.

[a] Interim Rept. Royal Sewage Commission, 1901, p. 304.

Of the disinfectants that have been sufficiently investigated, chlorine compounds and copper salts alone appear to be applicable to the sewage problem. Moreover, a detailed study of results on a cost basis leaves no doubt that the efficiency of chlorine is much greater than that of copper. Even if the prices of these two materials were more nearly equal, many facts favor the use of chlorine. Both reagents unite with organic matter, but chlorine unites by oxidizing the organic matter, thus rendering it less putrescible, while copper precipitates it. The compounds formed by the copper tend to protect the solid particles from further action, and the diffusion of copper ions through such a precipitated copper envelope must necessarily be slow. As no such action occurs with chlorine compounds, the penetration of the chlorine into solid particles must be much more complete. Chlorine in the form of bleaching powder is to some extent a by-product, is very cheap, and will probably become cheaper as the methods of production are improved; on the other hand, copper is a staple, the price of which is likely to increase. Sewages may be found of such chemical composition that treatment with copper will be more effective than that with chlorine, but in general chlorine compounds are to-day by far the most economical and the most efficient disinfectants available in sewage work.

EXPERIMENTAL INVESTIGATIONS.

HISTORY.

In connection with general investigations in sewage disposal, which have been conducted since 1903 at the sanitary research laboratory and sewage experiment station of the Massachusetts Institute of Technology, the subject of the chemical disinfection of sewage and sewage effluents has been extensively studied during the past two years. In the spring of 1906 a cooperative arrangement between the United States Geological Survey and the institute made it possible materially to enlarge the scope of the work.

With a view also of gaining increased knowledge of the practical workings of the processes that had been developed at Boston, an arrangement was made with the state sewerage commission of New Jersey, through Boyd McLean, secretary, under which experiments were begun at Red Bank, N. J. The state sewerage commission later continued that work for its own information, retaining the writer in charge, and through the courtesy of the commission the results of the entire work are here presented. During the summer of 1907 the experiments were placed under the immediate charge of F. E. Daniels, to whose faithful efforts their successful completion is in large part due. Mr. Daniels was assisted at Red Bank by H. S. Crawford, and also did much of the work at Boston during 1908.

In December, 1907, the scope of the investigation was still further broadened by a cooperative agreement between the United States Geological Survey and the sewerage commission of Baltimore, of which Brig. Gen. Peter Leary, U. S. Army, retired, is chairman, and Calvin W. Hendrick is chief engineer. Experiments on a somewhat enlarged scale were immediately undertaken at the Walbrook testing station of the Baltimore sewerage commission, and they were continued up to July, 1908, at which date the agreement with the Geological Survey lapsed. The work at Baltimore was under the immediate charge of Ezra B. Whitman, division engineer of the disposal division, to whom the writer is under the greatest obligation for its successful outcome. Intimately associated with that work also and responsible in large measure for the results have been Charles A. Emerson, jr., assistant division engineer, Henry C. McRae, chemist, and Edward G. Birge, bacteriologist. Dr. R. P. Cowles, of Johns Hopkins University, and William T. Carpenter, Leyland Whipple, and Marvin H. Lillis, have also been associated with this work from time to time in connection with special lines of investigation.

Through the courtesy of A. G. Paine, jr., president, and J. R. Crocker, superintendent, of the McDonald Electrolytic Cell Company, of New York, an electrolytic chlorine cell having a capacity of 22 pounds a day of chlorine gas was placed at the disposal of the writer, and it proved to be of great assistance in the work, as a large supply of gaseous chlorine was thus made available for special experiments. The machine was used directly in disinfection and also in the preparation of a series of chlorine compounds that were studied.

BACTERIOLOGICAL METHODS AND EXPRESSION OF RESULTS.

The bacteriological methods employed in the different parts of this work have been kept as nearly uniform as possible in order that the results may be strictly comparable. In general, the methods have been those recommended by the committee on standard methods of water analysis of the American Public Health Association, laboratory section. Since the publication of those methods,[a] a new presumptive test for the colon bacillus has been described by Jackson [b] and it has been used throughout this work. The medium employed in this test consists of ox bile to which lactose has been added. Its accuracy in sewage work has never been carefully studied, but recent studies by Prescott and Winslow [c] have confirmed the earlier statement of Jackson that in water work this presumptive test gives results which are similar to those obtained in complete *B. coli*

[a] Jour. Infect. Dis. Suppl. 1, Chicago, 1905. Repts. and Papers American Pub. Health Assoc., vol. 30, pt. 2, 1905.

[b] Biological studies by the pupils of William Thompson Sedgwick, p. 292, Boston, 1906.

[c] Elements of water bacteriology, 2d ed., New York, 1908, p. 149.

determinations. It may fairly be assumed, therefore, that the *B. coli* results reported in the present paper represent a group of bacteria, including practically all the *B. coli* actually present, together with certain other bacteria which probably are not more than 10 per cent of the whole number reported. The study of such a group gives valuable information concerning the probable elimination of typhoid and other pathogenic bacteria, while the additional information to be obtained from a complete determination of the *B. coli* actually present is not deemed sufficient to warrant the additional labor involved. At Boston and at Baltimore counts of the bacteria on gelatin at 20° C. and on litmus lactose agar at 37° C. and counts of the acid-forming bacteria at 37° C. were recorded. The latter group includes the *B. coli*, and some bacteriologists believe that the number of acid-forming bacteria is a more accurate indication of the numbers of colon bacilli than the presumptive tests. It is indisputable, however, that the group of acid-forming bacteria is large and that in sewage work at least it bears only a general relationship to *B. coli*. An additional group, the bacteria that liquefy gelatin, is also included in the Boston results, though the additional information afforded by including this group is slight. Inasmuch as adequate facilities for complete bacteriological work were not available at Red Bank, the total count at 20° C. and the presumptive *B. coli* tests alone were made. Examinations of the trickling filter effluent before and after treatment have been made at Boston on five or six days in each week. At Red Bank and at Baltimore two samples were tested each working day for *B. coli* and three samples were plated for the bacterial counts.

Considerable thought has been given to the manner of expressing results. It would obviously be inadvisable to attempt to tabulate the results of all examinations made, because such tables would be too unwieldy for general use. On the other hand, the use of averages, especially if they cover long periods, is open to the serious objection that a few bad results are easily covered up in general averages, and it is particularly necessary, in a process of this kind, to show that the results are not only satisfactory in general, but that they are fairly uniform. To cite a familiar illustration, a poor marksman's shots might be placed symmetrically about the center of the target and in that sense their average position might be as near the bull's-eye as the average position of better-placed shots. The actual deviations from the average position would indicate the character of the shooting. Similarly, in disinfection two series of tests might give the same average, even if one series were composed of fairly uniform results and the other series of very erratic ones. In other words, the deviations from the average are fully as significant as the average figure itself. Accordingly, the routine work is reported

in the form of weekly averages. The total bacterial counts are accompanied by a statement showing the variations of the individual results and the variations of the individual bacterial removals from the average bacterial removal. In this way the record of what was actually accomplished is stated in the most compact form.

A new method of recording *B. coli* results is also employed. The procedures used in the determination of this organism do not permit a quantitative count of the number really present, but show merely the presence or the absence of the bacillus. Quantitative results are obtained in a rough way by applying the test to various dilutions of the sample. For instance, in a disinfected effluent the test is applied on 0.1, 0.01, and 0.001 cubic centimeter, respectively, and the highest dilution giving a positive test is recorded. Hitherto a bare statement of the results is all that has been attempted in the way of giving quantitative significance to this test. But it has been shown [a] that where as many as fifty or one hundred results of that character from the same source are available, the probability law of distribution may be applied in order to estimate the average number of organisms present. The most probable value for the number of *B. coli* present in each sample is indicated by the reciprocal of the highest dilution giving a positive test, and while that figure may be far from the correct one for any one sample, the average of fifty estimates of this character closely approximates the actual value. The case is analogous to the well-known facts in relation to the expectancy of life at any age; an expectancy of life as given in the actuarial tables has but little weight when applied to any one person, but in the average of a large number of persons it approximates the truth. The number of *B. coli* present in a sample has therefore been recorded in this way. Individual results have but little weight and weekly averages must be properly interpreted, but monthly averages are probably very near the average numbers.

INVESTIGATIONS AT BOSTON.

SCOPE AND CHARACTER OF EXPERIMENTS.

Since the beginning of the work at Boston in February, 1906, various phases of the disinfection problem have been under investigation. The following summary of the studies shows their scope and character: (*a*) Preliminary experiments with chloride of lime; (*b*) studies of the comparative efficiencies of chloride of lime, sulphate of copper, and sodium benzoate; (*c*) small-scale experiments to determine the comparative efficiencies of free chlorine, commercial hypochlorites, electrolytic hypochlorites, chlorates and perchlorates, and the hypochlorites of several bases; (*d*) studies of the comparative effect

[a] Phelps, E. B., A method for calculating the numbers of *B. coli* from the results of dilution tests: Am. Jour. Pub. Hyg., vol. 18, 1908, p. 141.

of hypochlorites on the typhoid and the colon bacilli; (*e*) routine disinfection of 5,000 gallons a day of trickling-filter effluent with chloride of lime; (*f*) disinfection of crude sewage with chloride of lime in 700-gallon tests. The studies on copper sulphate and sodium benzoate have already been discussed (pp. 29–32). The remaining divisions of the work are reviewed in the succeeding pages.

PRELIMINARY EXPERIMENTS WITH CHLORIDE OF LIME.

The results of some preliminary experiments in the spring of 1906 have already been published,[a] but as they have important bearing on the present work, a brief review of them is here presented. The experiments were made with chloride of lime and the effluent of a trickling filter in which Boston sewage was being treated. They consisted of 23 bottle tests in which the available chlorine that was added varied from 0.25 to 100 parts per million, and the time of contact from thirty minutes to twenty-four hours. They were undertaken with the object of establishing practical working limits for available chlorine and contact period for future experiments, and particularly to determine whether the English and Continental practice of adding large, almost prohibitive, amounts of chlorine is justified by the results.

This preliminary study indicated that an effluent similar to the one used can be deprived of 95 per cent to 98 per cent of its total bacteria in two hours by the application of chloride of lime in concentrations having 2 to 5 parts per million of available chlorine. The impracticability of attempting to get much better results was well shown, for complete sterilization was never accomplished, though concentrations of chlorine up to 100 parts per million and storage periods of twenty-four hours were employed. It was found unnecessary, in brief, to use more than 5 parts of chlorine or to treat for over two hours.

It is a well-known fact that, in all processes involving the destruction of bacteria, it is comparatively easy to kill the first 95 per cent of the germs and very difficult to destroy the remaining 5 per cent. This phenomenon of the "resistant minority," as Whipple terms it, is common to all kinds of sterilization, whether it be by heat, cold, light, chemicals, or other means. It is therefore more practical to determine how far disinfection may be carried at a reasonable expenditure than to attempt the ideal complete sterilization. To state a concrete example, it might happen that the pathogenicity of an effluent could be reduced 96 per cent by the expenditure of a certain sum of money, 97 per cent by the expenditure of twice that sum, and 99 per cent by the expenditure of five times that sum. The first reduction might represent a feasible plan, and the last a pro-

[a] Phelps, E. B., and Carpenter, Wm. T., The sterilization of sewage filter effluents: Tech. Quart., vol. 19, 1906, pp. 382–403.

hibitively expensive one. It is plainly more desirable at the outset to determine the relations between the various factors, such as concentration of disinfectant, time of contact, cost, and efficiency, and to establish certain working limits with reference to final costs, than to attempt the ultimate destruction of all germs regardless of the practical limits that necessarily exist. The preliminary experiments were undertaken with the idea of fixing these practical working limits. For the first time in the history of the subject the disinfection of sewage filter effluents and even of crude sewage itself was shown to be practicable and feasible, yielding results commensurate with the cost when compared with the results and costs of other purification processes.

DISINFECTION OF TRICKLING-FILTER EFFLUENT.

The most important work at Boston consisted in the routine disinfection of the combined effluents of two trickling filters. Each filter is 8 feet deep and has a surface area of 50 square feet. One is composed of crushed stone from 1 inch to 1½ inches in mean diameter; the other of stone from 1½ to 2 inches in diameter. The combined effluents, amounting to 5,000 gallons in twenty-four hours, were brought from the underdrains of the outdoor trickling filters to the filter house through a short length of iron pipe. Within the filter house the liquid was conducted by an open trough to the central channel of a sedimentation tank built on the Dortmund plan. It then passed downward nearly to the bottom of this conical tank, entered the main body of the tank, and, rising with constantly decreasing velocity, finally overflowed at the surface. The tank was designed to give a two-hour storage period. The disinfectant solution was made up in a 50-gallon barrel to a strength about one hundred times that required in the final mixture. A small orifice-box working under constant head was connected with the barrel and was designed to deliver exactly 2 gallons an hour. As the flow through the sedimentation tank was a little over 200 gallons per hour, this arrangement gave a final mixture of the desired proportions. These rates and volumes were kept constant throughout, any change in the amount of disinfectant added being brought about by changing the strength of the solution. Readings of a float gauge set in the barrel and daily measurements of the flow of the trickling-filter effluent into the tank served as checks on the accuracy of the dilutions, and together with daily analyses of the strong disinfecting solution, gave data from which the actual amount of disinfectant added during any required period of time could be computed. Observations of the rate of flow of the disinfectant solution into the tank were made at hourly intervals for a period of three hours preceding the taking of samples, and the actual concentration of the disinfectant corresponding to the sample in question was

calculated from these observations. The disinfectant solution flowed into the open trough previously mentioned, where it mingled with the effluent. Further opportunity for mixing occurred during the passage down the central channel of the sedimentation tank. Samples for bacterial examination were collected with the usual precautions, before the effluent had reached the wooden trough into which the disinfectant solution was run and also at the final outlet of the sedimentation tank after the combined effluent and disinfectant had been in contact for a period somewhat less than two hours. These samples are described as initial and final, respectively.

The chemical composition of an effluent has an important influence on the germicidal value of most disinfectants, particularly chloride of lime. The chlorine applied is eventually completely consumed by chemical reaction with the organic matter of the effluent, and the germicidal action takes place in the interval of time between the addition of the chlorine and its final exhaustion by chemical reaction. The amount of organic matter present, therefore, practically determines the amount of chlorine that it is necessary to use. For this reason the chemical analyses of the combined effluent are recorded by monthly averages in Table 16. The monthly averages of the analyses of the disinfected and settled effluent are also included to show the chemical character of the effluent after treatment.

TABLE 16.—*Chemical analyses of trickling-filter effluent at Boston before and after disinfection with chloride of lime and sedimentation; monthly averages.*

[Parts per million.]

INITIAL.

Month.	Turbidity.	Suspended solids.		Nitrogen as—					Oxygen consumed.[a]		Dissolved oxygen.
		Total.	Loss on ignition.	Organic.		Free ammonia.	Nitrites.	Nitrates.	Total.	Dissolved.	
				Total.	Dissolved.						
1907.											
November	135	118	78	3.5	1.5	15.0	0.2	2.0	40	32	8.2
December	155	.....	.....	5.5	3.0	15.5	0.1	1.0	38	33	7.8
1908.											
January	140	92	69	5.0	3.0	15.0	0.3	3.5	45	38	10.0
February	145	177	156	6.0	2.5	14.5	0.1	3.0	44	32	12.5
March	130	180	122	7.5	3.5	15.5	0.2	4.0	48	35	7.8
April	195	313	192	10.5	5.5	14.5	0.4	5.5	64	46	9.4
May	275	436	247	14.0	4.5	14.5	0.6	6.0	70	35	7.4
June	155	174	96	11.5	6.0	7.5	0.8	6.0	49	35	7.1
Average	165	213	137	8.0	4.0	14.0	0.4	4.0	50	36	8.8

FINAL.

1907.											
November	105	71	53	3.0	1.5	14.5	0.1	2.0	28	27	.....
December	145	.....	.....	4.0	1.5	14.0	0.1	2.0	39	38	.....
1908.											
January	115	124	103	3.0	3.0	13.0	0.6	5.0	49	41	.....
February	110	259	239	4.5	2.5	13.5	0.3	4.5	42	38	.....
March	125	125	82	9.5	3.5	15.0	0.3	3.5	46	42	.....
April	105	147	125	5.5	3.5	14.5	0.4	5.0	44	40	.....
May	135	92	69	5.0	3.0	15.0	1.0	5.0	44	33	.....
June	95	51	43	7.0	4.0	7.5	0.8	6.0	38	33	.....
Average	115	124	102	5.0	3.0	13.5	0.5	4.0	41	37	.....

[a] Thirty-minute boiling method.

This disinfection experiment was started November 11, 1907, and was continued practically without interruption till June 27, 1908, a period of thirty-three weeks. The value of such continuous experiment is obvious. A certain length of time is always required for for the establishment of uniform working conditions, not only in the personal element but in the tanks themselves. Furthermore, short special experiments receive an unusual and perhaps unfair amount of care and attention, which is not bestowed on work that has become part of the routine, and the natural defects of the processes under practical working conditions are, therefore, not always discovered. The most important value of long-continued tests, however, lies in their being carried out under various seasonal conditions. Fluctuating conditions of temperature and rainfall fundamentally affect the sewage and influence the work of the filter. It is consequently of prime importance to determine the efficiency of any purification process under an extreme range of seasonal conditions. It fortunately happened that the present experiments were continued through an unusually cold winter and through the hottest portions of an exceptionally hot, dry summer.

Table 17 contains the results of the experiments, given in weekly averages, which are the mean of four to six daily results. During the first five weeks the available chlorine added was about six parts per million, but during the remainder of the period this concentration was reduced to between two and four parts without materially affecting the results. The average results for the whole period are indicated in the last line of the table.

TABLE 17.—*Disinfection of trickling-filter effluent with chloride of lime at Boston; weekly averages.*

Week ending—	Temperature.	Available Cl (parts per million).	Number of bacteria per cubic centimeter at 20° C.				Number of bacteria per cubic centimeter at 37° C.				Number of B. coli per cubic centimeter.[a]	
			Total.		Liquefiers.		Total.		Acid formers.			
			Initial.	Final.	Initial.	Final.	Initial.	Final.	Initial.	Final.	Initial.	Final.
1907.												
November 16	45	5.7	1,100,000	1,800	150,000	100	330,000	570	250,000	22	260,000	4
23	46	5.9	800,000	7,500	46,000	600	130,000	500	94,000	250	180,000	20
30	42	6.8	1,000,000	1,800	48,000	43	65,000	600	48,000	110	26,000	1
December 7	36	6.9	600,000	4,500	60,000	90	140,000	140	85,000	44	17,000	0
14	42	5.0	800,000	15,000	60,000	750	140,000	1,500	43,000	850	5,500	33
21	37	3.0	550,000	85,000	27,000	4,500	95,000	6,500	75,000	5,500	4,000	370
28	44	3.1	850,000	20,000	120,000	2,400	210,000	3,400	66,000	1,900	46,000	600
1908.												
January 4	40	2.8	950,000	7,000	70,000	500	90,000	500	70,000	370	65,000	25
11	35	3.2	550,000	17,000	55,000	450	86,000	2,100	50,000	1,900	55,000	750
18	34	2.7	550,000	22,000	47,000	1,300	80,000	1,300	80,000	1,200	8,500	520
25	35	2.7	800,000	35,000	26,000	2,800	110,000	6,000	100,000	5,500	64,000	60
February 1	34	3.3	450,000	75,000	30,000	4,000	70,000	16,000	55,000	11,000	2,500	230
8	33	3.6	800,000	8,000	60,000	400	340,000	2,000	200,000	1,100	10,000	100
15	35	3.4	650,000	43,000	30,000	250	60,000	2,500	50,000	2,000	33,000	280
22	34	3.4	390,000	17,000	24,000	900	74,000	2,600	52,000	2,000	10,000	400
29	34	3.3	550,000	13,000	40,000	100	90,000	3,400	60,000	2,500	33,000	750
March 7	35	3.8	430,000	3,400	30,000	190	140,000	2,300	75,000	1,500	40,000	70
14	38	3.1	500,000	18,000	35,000	700	170,000	5,500	120,000	4,500	25,000	550
21	38	3.0	600,000	7,500	65,000	320	180,000	2,200	140,000	1,800	55,000	360
28	42	2.5	460,000	18,000	36,000	500	140,000	5,700	95,000	4,500	25,000	700
April 4	40	3.2	450,000	8,000	60,000	1,400	140,000	3,000	80,000	2,200	40,000	240
11	42	2.4	2,500,000	37,000	500,000	6,000	160,000	8,500	90,000	4,400	10,000	1,000
18	42	1.7	1,100,000	35,000	220,000	6,000	160,000	4,300	75,000	2,000	70,000	850
25	46	2.7	600,000	100,000	70,000	2,400	150,000	7,500	75,000	2,300	46,000	806
May 2	54	3.4	450,000	2,000	60,000	200	250,000	1,000	55,000	300	55,000	55
9	48	3.1	600,000	23,000	180,000	5,500	210,000	2,200	140,000	900	25,000	400
16	56	3.0	600,000	9,000	85,000	1,200	120,000	1,800	32,000	1,600	40,000	200
23	58	2.6	1,400,000	28,000	220,000	2,400	280,000	11,000	170,000	9,000	85,000	1,000
30	62	2.7	700,000	18,000	130,000	3,800	230,000	6,000	160,000	350	64,000	800
June 6	61	2.8	850,000	34,000	100,000	3,800	190,000	4,600	150,000	3,500	85,000	850
13	68	2.5	550,000	35,000	160,000	1,500	75,000	3,200	55,000	1,500	40,000	200
20	68	2.8	630,000	32,000	120,000	3,600	110,000	4,800	60,000	1,500	8,000	62
27	68	3.0	1,100,000	13,000	120,000	1,300	210,000	5,700	50,000	300	2,800	200
Average	45	3.4	750,000	24,000	95,000	1,800	150,000	3,900	90,000	2,400	47,000	380

[a] Jackson bile media used.

The average efficiencies as measured by the per cent of bacteria removed for the whole period and for certain shorter periods, selected to illustrate the effect of different concentrations of chlorine and of fluctuating conditions of temperature, are shown in Table 18.

TABLE 18.—*Disinfection of trickling-filter effluent at Boston; summary of bacteriological results, averaged by periods, to show the effect of changes in temperature and in the amount of available chlorine.*

Period.	Temperature.	Available chlorine, in parts per million.	Per cent of bacteria removed.				
			Bacteria at 29° C.		Bacteria at 37° C.		
			Total.	Liquefiers.	Total.	Acid formers.	*B. coli.*
	° F.						
November 12 to June 27	45	3.4	96.8	98.1	97.4	97.3	99.19
November 12 to December 12	42	6.3	99.57	99.73	99.81	99.91	99.99
January 27 to March 28	36	3.2	95.8	97.7	96.6	96.4	98.5
April 27 to June 27	60	2.9	97.1	98.0	97.6	97.9	99.07

Comparison of the results obtained in the periods November 12 to December 12 and January 27 to March 28 shows that the additional bacterial removal gained by increasing the available chlorine from 3.2 to 6.3 parts per million, although it is considerable in amount, is hardly commensurate with the cost. The effect of temperature on the bacterial removal is shown in the periods from January 27 to March 28 and April 27 to June 27. The mean temperature is 36° F. in one period and 60° F. in the other, while the available chlorine is practically the same in both periods, though slightly higher during the period of lower temperature. An advantage in favor of the summer results is noticeable, and it would probably have been a little greater with exactly the same amount of chlorine. Yet the results show especially that the effect of temperature on efficiency is not great. This point is of special significance in comparing the results of chlorine disinfection with those obtained with copper. In experiments with copper, temperature has been shown to produce a marked effect; in fact, the concentration of copper must be doubled during the winter months to maintain the efficiency of the process. The bacterial removals in the several groups of bacteria recorded are nearly the same, though the removal of *B. coli* is higher in all experiments. It is probably safe to assume that the removal of the typhoid and other pathogenic organisms will be as nearly perfect as the removal noted in any of these groups. The per cent removals of organisms shown by the counts at 37° C. and by the *B. coli* results probably represent most nearly the per cent removal of typhoid bacilli.

As has been stated, the reliability of a disinfection process depends quite as much on the general evenness of the results as on the aver-

age efficiency. For that reason the per cent removal of total bacteria has been computed for each of the 158 individual tests, and the results of the calculations, given in Table 19, show that the per cent removal was between 98 and 100 per cent in over half the individual tests, and that it was less than 94 per cent in only 15 per cent of the tests.

TABLE 19.—*Relation between individual tests of bacterial removal and the average result at Boston.*

Per cent of total number of tests.[a]	Per cent removal of total bacteria.	
	Not less than—	Less than—
54	98	100
19	96	98
12	94	96
6	92	94
2	90	92
3	85	90
2	75	85
2	65	75
Total, 100	Average, 96.3	

[a] Number of individual tests, 158.

The number of bacteria remaining in the disinfected effluent have been tabulated in a similar manner, in order that the bacterial quality of the final effluent may be properly understood. The results are given in Table 20.

TABLE 20.—*Relation between individual bacterial counts and the average result at Boston.*

Per cent of total number of tests.[a]	Total number of bacteria per cubic centimeter.	
	Not less than—	Less than—
47	100	10,000
23	10,000	25,000
20	25,000	50,000
5	50,000	100,000
3	100,000	200,000
2	200,000	250,000
Total, 100	Average, 24,000	

[a] Total number of tests, 158.

The average of the 158 individual tests of bacterial removal is 96.3 per cent, as compared with 96.8 per cent removal (see Table 17, p. 42) obtained from the average numbers for the whole period. The first figure is more nearly correct for estimating the efficiency of the process; but it is evident that the last figure, which is more commonly employed in such work, gives the average result with sufficient accuracy. The somewhat tedious calculation of the individual results

and their variations has been made only for the total bacteria; but the results suffice to show that the average per cent removal of bacteria, computed from the average initial and final counts, is practically the same as the average of the per cents calculated from the individual tests, and that there is a certain variation in the results to the extent shown. As to the other groups of bacteria studied, it is sufficient to state that similar computations with them gave practically identical results, subject to much the same deviations.

In order to study the effect of varying the time of contact with the disinfectant, samples of the trickling-filter effluent were collected from the mixing trough after the disinfecting solution had been added. After these samples had been well shaken, determinations were made of the number of bacteria remaining at the end of ten minutes, fifteen minutes, one hour, and two hours, the sample being shaken each time before withdrawing the test portion. The number of bacteria in the effluent before treatment, as determined on a separate sample, was between 250,000 and 1,000,000 per cubic centimeter; but the numbers in all tests have been converted to a uniform basis of 1,000,000 initial bacteria per cubic centimeter for more ready comparison of the results in Table 21.

TABLE 21.—*Relation between time of contact and efficiency of disinfection with chloride of lime.*[a]

Date.	Number of remaining bacteria per cubic centimeter[b] after contact for—			
	10 minutes.	15 minutes.	60 minutes.	120 minutes.
August 6		1,100	160	150
9	2,500	190	58	7
10	10,000	270		40
11	3,500	570	154	100
14	47,000	1,100	700	570
15	4,200	310	120	120
16	1,200	240	160	130
17	9,800	800	260	150
20	400,000	12,000	7,000	5,500
21	28,000	2,100	1,300	1,000
23	1,300	230	110	31
Average	50,000	1,700	950	700
Per cent of remaining bacteria	5.0	0.17	0.10	0.07

[a] Available chlorine, 5 parts per million.
[b] All numbers converted to a uniform basis of 1,000,000 initial bacteria per cubic centimeter.

The rapidity of the action of the disinfectant is somewhat surprising, and it indicates that long periods of contact are unnecessary. It is evident that the greater part of the disinfection is accomplished within the first fifteen minutes, and that a contact period of one hour is probably ample for practical work. Another feature of interest in this experiment is its bearing on the character of the sediment in the disinfection tanks. It has been suggested that perhaps such sediment carries down with it large numbers of the bacteria that are

recorded as being removed, though they may be still vigorous within the protecting body of solid matter. It is undoubtedly true that ordinary sedimentation tanks remove a considerable number of bacteria, and the actual removal is doubtless even greater than would appear from the data, owing to multiplication during sedimentation. But in their slow descent through the liquid, such bacteria are subject to the action of the chlorine, the supply of which is constantly renewed by the downward movement of the particles. The major portion of such sediment is suspended in the liquid for periods varying from fifteen minutes to an hour, during which time the chlorine has evidently ample opportunity to act. In the series of tests just described this sediment was included in the bacterial determinations. It is interesting to note, therefore, that the average reduction of bacteria at the end of two hours was 99.93 per cent, while the routine tests on the same days in the sedimentation tank gave an average reduction of 99.96 per cent, results practically identical. The sediment is apparently as completely disinfected as the supernatant liquid, but naturally an accumulation of sediment at the bottom of the tank would soon rid itself of chlorine and permit the multiplication of the remaining bacteria. Such secondary growth of bacteria, however, has no sanitary significance, since it has been satisfactorily shown that the pathogens do not develop in such manner outside the body.

These results demonstrate the entire feasibility of satisfactorily disinfecting trickling-filter effluents with chloride of lime, and they indicate that about 3.5 parts per million of available chlorine and a contact period of about one hour are ample for an effluent like that on which the experiments were made. A general discussion of the results in their practical application to the disinfection problem with special reference to costs is given on pages 63–70.

DISINFECTION OF CRUDE SEWAGE.

Under certain circumstances it may be necessary and desirable to disinfect the crude sewage of a community, though such a procedure would not as a rule be considered. It can never take the place of purification except by the use of excessive amounts of disinfectant; and by destroying the bacteria always present it simply delays the natural processes of reduction, allowing them to proceed at a later time, possibly after the solid matter has had time to settle to the bottom of a stream where the greatest nuisance will be caused by its decomposition. It might happen, however, that a sufficiently great dilution to preclude anaërobic action and a sufficiently swift current or tidal flow to prevent sedimentation would obviate all danger of a nuisance except from a bacterial standpoint. Such conditions are,

perhaps, most nearly realized in our seaboard cities, where there may be no question of a physical nuisance, but where bacterial pollution of the harbor waters may be undesirable for various reasons.

The disinfection of crude sewage was studied because it was believed that experiments with the material might help to solve the general problem. The relations between available chlorine, amount of organic matter, and germicidal effect suggest that an excessive amount of organic matter in raw sewage might affect the efficiency of the chloride of lime treatment by combining directly with the chlorine and thus preventing its activity. The quality of the organic matter might also influence the result; for, as the organic matter of crude sewage is more readily oxidizable than that of an effluent, it might be expected to consume a greater amount of chlorine than the latter in a short time. The experiments with crude sewage were undertaken with the object of studying such features and of ascertaining the concentrations of chlorine necessary to effect a satisfactory removal of the bacteria in crude sewage, having in view both the possible disinfection of crude sewage itself and the establishment of a maximum limit of available chlorine in the treatment of effluents.

The details of these experiments differ somewhat from those of the effluent tests that have been described. In treating an effluent, sedimentation is an advantageous process by itself and can be usefully employed as an adjunct in disinfection, but in treating raw sewage, the removal by sedimentation of large amounts of organic matter in an unoxidized condition is undesirable and is not permissible in practice. In the experimental work, therefore, it was necessary to prevent sedimentation during the treatment.

A rectangular tank having a capacity of about 700 gallons was employed for the experiments. A 2-inch pipe led from the bottom of the tank to a pump with sufficient capacity to draw out the entire contents of the tank in half an hour. The outlet pipe from the pump discharged into the top of the tank, and the rapid circulation maintained in the sewage in this manner during the experiment made sedimentation of solids practically impossible. Before the beginning of the test the sewage was pumped through the system for fifteen minutes in order to insure thorough mixing; then a sample was collected for chemical and bacterial analysis, and the calculated amount of disinfectant solution was slowly poured into the inflowing stream. The force of this stream entering the tank from a height of about six feet churned the sewage thoroughly and assured rapid and complete mixing. Samples were collected at the end of the second and fourth hours for determination of the total bacteria growing at 20° C. and of the number of *B. coli*. The available chlorine employed

was ten parts per million. In the first series of tests the total amount of chloride of lime was added at first, but in the second series it was added in four portions at hourly intervals. The results are tabulated in Table 22.

TABLE 22.—*Disinfection of crude sewage with chloride of lime at Boston; series 1 and 2.*[a]

Series.[b]	Temperature.	Number of bacteria per cubic centimeter.		
		Initial.	At end of 2 hours.	At end of 4 hours.
	°F.			
1	44	700,000	4,900	13,000
	46	260,000	220	5,700
	50	750,000	10	100
	60	600,000	620	80
	60	200,000	500	100
	60	270,000	500	100
Average	54	460,000	1,100	3,400
2	56	600,000	700	190
	60	460,000	100	60
	60	360,000	260	40
	60	460,000	14,000	340
	60	280,000	22,000	200
	60	540,000	7,000	130
Average	59	450,000	7,500	160
Number of *B. coli* per cubic centimeter; average of both series		35,000	24	15

[a] Available chlorine, 10 parts per million.
[b] Series 1. Chlorine added at start. Series 2. Chlorine added in four equal hourly portions.

The average reduction of total bacteria in the first series was 99.76 per cent at the end of two hours, and, owing to multiplication of bacteria, 99.26 per cent at the end of four hours. In the second series the reduction in two hours was only 98.3 per cent, five parts per million of available chlorine having been added up to that time, and the addition of another five parts of chlorine brought the total reduction up to 99.96 per cent at the end of four hours. This indicates that there is a distinct advantage in adding the disinfectant in successive portions, but the increased efficiency in this case was not great, and it is doubtful whether it would generally be sufficient to compensate for the more complicated method of operation.

The figures for *B. coli* have little individual significance, but the average values indicate a removal of *B. coli* of 99.93 per cent and 99.97 per cent after two hours and four hours, respectively—values that are considerably better than those derived for the total bacteria. The results of the disinfection of crude sewage therefore agree with those obtained with the filter effluent. It is also apparent from these experiments that ten parts per million of available chlorine are ample to disinfect the crude sewage of Boston, and it is probable that even a less concentration would give satisfactory results. It is evident also that two hours is a sufficient contact period, little advantage being gained by making it longer.

In April, 1908, a third series of experiments with crude sewage was made to determine the minimum amount of chlorine and of contact time possible for satisfactory disinfection. These tests were essentially like those of the first series, except that the available chlorine was varied each day, so that on successive days it amounted to two, four, six, eight, and ten parts per million, respectively. On the sixth day it was started again at two parts. In this way the effect of chlorine concentration was studied with as little interference as possible from other variables, such as temperature and character of the sewage. A two-hour period of contact was given, and in addition to the initial sample, in each test, samples were collected after half an hour, one hour, and two hours. The results of this series are shown in Table 23.

TABLE 23.—*Disinfection of crude sewage with chloride of lime at Boston; series 3.*

Available chlorine (in parts per million).	Temperature.	Number of bacteria per cubic centimeter.			
		Initial.	One-half hour.	1 hour.	2 hours.
	° F.				
2	52	1,100,000	90,000	62,000	130,000
	58	1,600,000	320,000	470,000	870,000
	59	1,200,000	32,000	49,000	140,000
	53	900,000	47,000	16,000	42,000
	60	1,900,000	400,000	450,000	700,000
	64	1,700,000	370,000	460,000	1,000,000
4	54	2,100,000	50,000	41,000	65,000
	55	1,100,000	5,000	6,500	4,400
	59	1,400,000	30,000	40,000	85,000
	58	950,000	3,400	1,100	4,200
	60	1,900,000	12,000	11,000	23,000
	64	3,500,000	33,000	26,000	80,000
6	56	1,700,000	3,600	9,000	1,700
	58	1,700,000	6,500	600	6,000
	60	2,800,000	17,000	4,600	4,400
	57	1,700,000	1,700	8,400	3,900
	60	2,400,000	1,800	3,000	1,700
	64	3,300,000	14,000	11,000	18,000
8	55	1,600,000	570	480	600
	60	1,500,000	3,400	160	730
	59	2,000,000	2,000	1,100	3,700
	59	1,100,000	340	170	750
	63	2,600,000	1,900	2,700	3,300
	65	2,500,000	6,300	3,300	9,500
10	52	1,600,000	380	300	400
	57	610,000	200	210	200
	58	1,900,000	1,100	430	1,600
	62	1,100,000	350	800	1,100
	64	2,500,000	500	350	850
	64	3,100,000	3,500	2,300	4,800
Control	56	1,200,000	1,500,000	1,800,000	2,100,000

The results indicate that a large amount of chlorine is consumed by the sewage within two hours. Two parts per million are consumed within half an hour and ten parts per million are not sufficient to prevent the subsequent growth of bacteria. It has, however, already been pointed out that such subsequent growths have no significance and that the efficiency of the disinfection from the standpoint of the pathogenicity of the sewage is measured by the maximum reduction, independent of any subsequent increase.

The average initial and minimum figures and the per cent of bacteria removed for each concentration of chlorine are brought together in Table 24.

TABLE 24.—*Disinfection of crude sewage with chloride of lime at Boston; summary of results.*

Available chlorine (in parts per million).	Average number of bacteria per cubic centimeter.		Bacteria removed.
	Average initial.	Average minimum.	
			Per cent.
2	1,400,000	210,000	85
4	1,800,000	23,000	98.7
6	2,200,000	6,000	99.7
8	1,900,000	1,200	99.94
10	1,800,000	700	99.96

These experiments were not sufficiently prolonged to furnish complete data on the process, and it is not at all unlikely that at another season of the year somewhat different results might have been obtained, though it has been shown in connection with the work on effluents that the temperature effect on the disinfection itself, other conditions remaining constant, is but slight. The bacterial and chemical composition of crude sewage, however, is affected by temperature to a much greater extent than is that of filter effluents. The amount of dissolved oxygen present is an important index to the character of the sewage or the effluent in reference to its effect on chlorine; absence of dissolved oxygen in particular indicates ready oxidizability, which in turn means the rapid absorption of chlorine. It is probably true that a given amount of chlorine acting for a given time will bring about a definite reduction in the total number of bacteria, regardless of the character of the treated liquid. Unless excessive amounts of chlorine are added, however, the time of contact is determined by the character and the amount of the organic matter in the sewage; consequently the more rapidly the chlorine is exhausted by this organic matter the shorter is the time of contact and the less is the bacterial reduction. The sewage experimented with in these tests represents about an average condition in regard to reducibility, and it contained about one-half the amount of dissolved oxygen that would be found during the winter months. Results fully as satisfactory as these could doubtless be obtained during six months of the year with even less available chlorine. During the summer months, when dissolved oxygen is not present, more chlorine than is here indicated would be found necessary. The Red Bank experiments on septic sewage make it probable that a concentration of ten parts per million of available chlorine may be taken as a maximum amount during the summer.

Satisfactory disinfection of crude Boston sewage can be accomplished by adding chloride of lime in such amounts that the available

chlorine will amount to about five parts per million during six months of the year, and to between five and ten parts during the other six months, or an average amount during the year of seven or eight parts per million. The addition of the disinfectant in portions at intervals during the treatment yields results that are somewhat better than those obtained by adding the entire amount at once, but it is not probable that this advantage is commensurate with the additional complications involved.

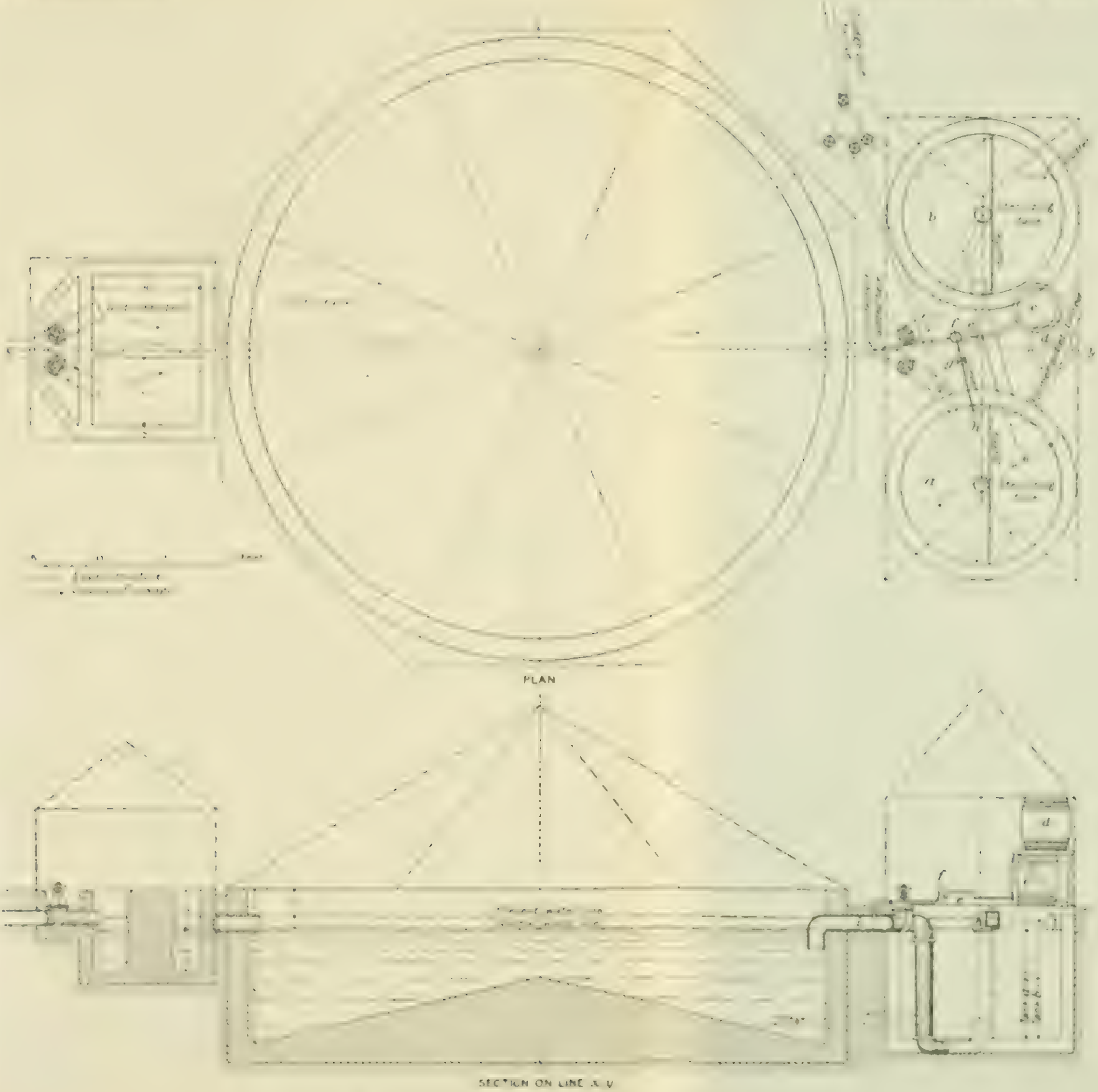
DISINFECTION OF SEPTIC SEWAGE AT RED BANK, N. J.

The successful results obtained in the disinfection of trickling-filter effluents at Boston in 1906 warranted the extension of the experiments to include a practical demonstration; and that step was made possible through the cooperation of the New Jersey State Sewerage Commission. Red Bank, a town of about 6,500 inhabitants, situated on Navesink River in Monmouth County, was selected for the tests for two reasons: The works at Red Bank were so arranged that the experiment could be undertaken at a minimum expense for new construction; and, like many other communities in that section of the State, the town was discharging partly-purified sewage into waters that shortly reached important shellfish areas. A septic sewage of rather poor quality was to be treated. Work with an effluent of higher grade had been desired, but the novelty of treating a septic sewage and the immediate practical value of the results promised to make this experiment well worth undertaking. The conditions resembled those described on pages 12–13, where it was suggested that in certain localities thorough disinfection of crude or septic sewage will go far toward accomplishing all that is needful. At least the most necessary step is thus taken first, and it is a logical first step in the gradual improvement of sanitary and economic conditions along our water fronts.

It was realized that more chloride of lime would be needed than had been used in previous experiments, but how much more was not known. The Boston results with crude sewage were not available at that time, and it was to be expected that, owing to the highly unstable character of septic sewage, even more chloride of lime would be necessary than for crude sewage. The work was started in October, 1906. During the fall the disinfection apparatus was left to the care of a local attendant, and a representative of the commission visited the works twice a week to collect samples for analysis; but mechanical deficiencies in the dosing device led to intermittent and irregular dosing, so that the results obtained were far from satisfactory, and considerable time was consumed before it was learned that more than 10 parts per million of available chlorine would be required. The work was discontinued when cold weather began, but it was resumed under more favorable circumstances in the summer of 1907. A laboratory in charge of Mr. Daniels was installed at the works, and

the entire experiment was then under careful observation, for samples could be taken and examined as frequently as might be desired. The results amply justified this course. The earlier work indicated the probable strength of chlorine necessary, and developed many defects and weaknesses in the dosing apparatus, all of which were remedied. The investigations that were conducted during the summer of 1907 only are reported.

The sewerage system of Red Bank is constructed on the separate plan, with special drains to carry off rain water. On account of the sandy nature of the soil and the poor construction of the sewers considerable storm water finds its way into the sewers. The average dry-weather flow of sewage is about 265,000 gallons a day. The following description of the disposal works will be more readily understood by referring to Plate I. After entering the works the sewage divides into two streams, passing through two grit chambers, each 5 by 8 feet in plan and 3 feet deep to the flow line. The flow may be entirely diverted through either tank to allow the other to be cleaned out. From these chambers the sewage flows to the septic tank, which is circular in plan, 43 feet in diameter, with a normal depth to the flow line of 8 feet 6 inches at the periphery and 5 feet at the center, the bottom being conical. Its capacity at that depth is about 82,000 gallons, or approximately an 8-hour dry-weather flow. For the purpose of these experiments, however, it was necessary to raise the flow line throughout the system 1 foot, a change that increased the capacity of the tank to about 93,000 gallons. At the side of the tank opposite the entrance pipe the septic sewage passes out through a submerged 12-inch pipe *i*, which later divides into a Y. A branch then runs downward to the bottom of each of the filters, thence horizontally to a point beneath the center, thence upward into the filter, as shown in the sectional view. The so-called filters are two in number, and each is 12 feet in diameter. Tank *a* is 9 feet deep to the flow line, with a capacity of 7,600 gallons, and tank *b* is 8 feet 3 inches deep, with a capacity of 7,000 gallons. The tanks were originally filled with stone and brick over a false bottom and were practically strainers for the removal of suspended matter. Each filter is provided with a 12-inch overflow leading to a manhole outside the building. For these experiments the filtering material was entirely removed from both tanks, one of the outlets was closed, and a cross-connection was put in to conduct the sewage from the top of the first tank to the bottom of the second. By closing the inlet valve of the latter the entire flow was made to pass through the two tanks in series. Suitable baffles were provided, as indicated in the plan, so that the entire capacity of the tanks could be utilized to the best advantage. As thus arranged, each tank held about forty-five minutes' flow, and the efficiency of the process was tested at the end of forty-five minutes and ninety minutes.



PLAN OF SEWAGE-DISPOSAL WORKS AT RED BANK, N. J.

Chloride of lime was used throughout the work. For the preparation of the solution two hogsheads *c* and *d* of about 240 gallons capacity each were provided, one elevated over the other. In the upper hogshead the requisite amount of bleaching powder was mixed with water and allowed to settle over night. The next morning the clear supernatant liquid was drawn into the lower hogshead. The latter was connected directly with a constant-level tank *e*, controlled by a ball cock, on which a glass ball and special fittings were necessary to prevent corrosion. The constant-level tank was connected by a flexible rubber tube with the dosing tank *f*—a box 6 by 6 inches in plan and 8 inches deep—provided with a three-sixteenth-inch orifice in one side and suspended on one end of a 6-foot lever *g*, the other end of which was connected with a large float *h* in tank *a*. Tank *a* was provided at its outlet with a 1-foot weir, by which the water level was made to vary with the flow. An increase in the flow increased the elevation of sewage in the tank, thus raising float *h* and lowering the suspended box *f* at the other end of the lever. Since box *f* was connected with the constant-level tank *e*, the effect of such change was virtually to increase the head over the orifice. In this manner the flow of the hypochlorite solution was automatically kept about proportional to the flow of sewage. The ratio was not exact, because the variation in flow with the head is not the same with a weir as with an orifice, but within the range of flows used the arrangement was quite satisfactory. By discharging the sewage from tank *a* through a submerged pipe instead of over a weir the ratio between the two flows could be kept the same at all heads. A suitable gage was erected in tank *a*, and the elevation of the sewage over the weir crest was recorded at intervals of two hours from 6 a. m. to 6 p. m., or more frequently during storms. These readings were converted into gallons, and the daily discharges of sewage were calculated from them. The night flow was approximately determined by calculations based on two sets of hourly observations extending over twenty-four hours and on the relation of these sets of data to the general averages of day flows. When the weir gage was read, readings were also taken of a gage in the hogshead *c*, calibrated to read directly in gallons. By this means the hourly flows of disinfectant solution were known at all times and could be compared with the corresponding sewage flows.

The solution of bleaching powder was run into the septic tank outlet pipe *i*, where it mixed with the main flow of sewage. The treated sewage then passed through the two disinfecting tanks *a* and *b* and was finally discharged into the river. The extraction of the hypochlorite was not complete in the one leaching given it. In mills where large quantities of it are extracted three successive lixiviations are customary in order to complete the extraction, but such practice was not feasible here, and the sludge remaining each

day in hogshead *d* was dumped into tank *a*, where it settled to the bottom and was slowly leached out by the sewage. In this way all the available chlorine was utilized.

It was necessary to have some information about the chemical composition of the septic sewage under treatment and to make certain chemical tests of the effluent. For this purpose samples of the septic sewage and of the disinfected effluent were collected daily and determinations of the oxygen consumed were made on them. These estimates gave a comparative indication of the strength of the sewage from day to day. Daily determinations of dissolved oxygen in the final effluent were also made, and the effluent was tested for free chlorine. The septic sewage never contained any dissolved oxygen, and under normal conditions the effluent would be in the same condition, but the application of free chlorine to sewage gives rise to chemical reactions, whereby free oxygen is formed. This is largely consumed in the oxidation of the organic matter, but nevertheless some free dissolved oxygen was always found in the effluent. The presence of this oxygen is of great value in the further self-purification of the sewage after reaching the river. Free chlorine was never found in the final effluent. Its presence would be highly injurious to fish life, and disinfection processes of this nature must always be so controlled that no injurious chemical can escape into the stream. In addition to the daily determinations just mentioned, composite sterilized samples were preserved and sent to Boston regularly, where they were submitted to complete chemical analysis. Regular chemical analyses of the bleaching powder and daily assays of the disinfectant solution were made.

The results of the work at Red Bank are given in the form of weekly averages in Table 25, and the relation between the individual and the average results are shown in Table 26.

TABLE 25.—*Disinfection of septic sewage with chloride of lime at Red Bank, N. J.; weekly averages.*

Week ending.	Available chlorine in parts per million.	Total number of bacteria per cubic centimeter at 20° C.			Number of B. coli per cubic centimeter.[a]		
		Initial.	At end of 45 minutes.	At end of 90 minutes.	Initial.	At end of 45 minutes.	At end of 90 minutes.
1907.							
July 20	9.9	800,000	410	460	46,000	4	4
27	10.6	650,000	800	420	80,000	13	11
Aug. 3	11.5	1,800,000	550	130	40,000	21	5
10	11.4	850,000	240	140	55,000	14	2
17	13.0	760,000	2,100	1,500	70,000	30	28
24	7.3	700,000	45,000	55,000	70,000	700	600
31	7.5	1,200,000	45,000	26,000	220,000	16,000	2,000
Sept. 14	11.8	750,000	13,000	8,000	300,000	150	140
21	13.1	750,000	850	800	500,000	270	260
28	10.5	700,000	120	88	550,000	80	28
Average[b]	11.5	900,000	2,200	1,400	205,000	75	60

[a] Jackson bile media used. [b] Exclusive of period August 19–31; temperature 56° to 58° throughout.

TABLE 26.—*Relation between individual tests of bacterial removal and the average result at Red Bank, N. J.*

Per cent of total number of tests.[a]	Total number of bacteria per cubic centimeter.	
	Not less than—	Less than—
84	100	1,000
5	1,000	2,000
5	2,000	5,000
6	5,000	.....
Total, 100	Average, 1,900	

[a] Total number of tests, 224.

During the period August 19 to August 31, the available chlorine was reduced to about 7.5 parts per million. A removal of the total bacteria amounting to about 95 per cent and of *B. coli* amounting to 94.3 per cent after three-quarters of an hour and 99 per cent after one and a half hours was obtained, but the individual results were very erratic, and it was apparent that an insufficient amount of chlorine was being added. The chlorine was therefore increased again to about 12 parts per million and kept there during the remainder of the experiment. The averages in the last line of Table 25 do not include the results for the above-mentioned period. The average per cent removal of total bacteria was 99.7 at the end of 45 minutes, and the corresponding *B. coli* figure is 99.96. In 90 minutes the average per cent removals were 99.8 and 99.97, respectively. It is rather striking that such results can be obtained with 12 parts per million of available chlorine, while the results are poorer and very erratic with 7.5 parts. The explanation is probably found in the character of the sewage, which was very concentrated in its raw state and had passed through a septic tank that was working vigorously. A large amount of hydrogen sulphide was contained in the septic sewage. The characteristic odor of this substance was extremely noticeable in the vicinity of the works, and the addition of chlorine to the sewage produced a milkiness, due to the liberation of free sulphur. Titration of the septic sewage in the cold with potassium permanganate, a substance less easily reduced than chlorine, indicated that enough hydrogen sulphide and other easily oxidizable substances were present to reduce instantly about five or six parts per million of chlorine. Consequently the efficient results in this experiment were in reality obtained with about six parts of available chlorine and the poor ones with about three parts.

The disinfection of septic sewage evidently requires so much chlorine that the expense will be considerable. It will probably be found to take twice as much chlorine for septic sewage as for the cor-

responding crude sewage. The combination of septic action and disinfection eliminates the suspended matter and the bacteria from the sewage and in many localities would constitute a very desirable system. In practice, however, the order of the processes should be reversed. The disinfection of the crude sewage can be done in a small tank of an hour's capacity. The disinfectant should be so regulated that little or no chlorine would flow into the septic tank. Unless a considerable amount of chlorine should thus escape at one time there would be no objectionable effect on the action in the tank. There would be a great multiplication of bacteria in the tank, so that the number in the final effluent would probably be as great as in the raw sewage, and perhaps even greater. Nevertheless, the disinfection would be as effective on the pathogens as if it were applied as a final process. The subsequent development of saprophytes would have no sanitary significance and would doubtless be of real value in the subsequent self-purification of the organic matter after it had been discharged into the stream.

DISINFECTION OF TRICKLING-FILTER EFFLUENT AT BALTIMORE.

Reference was made in the history of the experiments to the cooperative arrangement between the United States Geological Survey and the Baltimore sewerage commission. In December, 1907, the sewerage commission undertook a study of disinfection methods at its Walbrook testing plant. The writer assisted in planning this work, and was consulted from time to time during its progress. The disinfection experiments were made a part of the routine work of the testing station, and they were carried out by the station staff. A complete review of this investigation, the most important and most comprehensive one on the subject ever conducted, will, it is hoped, be made by the sewerage commission in the near future. The present report has been made as brief as possible and includes only the work done before June 30, 1908.

The Walbrook testing plant, in the extreme western section of Baltimore, was built for use in investigating certain problems in connection with the disposal works now being built at Back River, the main features of which—screening, sedimentation, treatment on trickling filters, and final sedimentation—had already been decided upon. Information was specially desired as to the probable bacterial efficiency of such a process and as to the necessity for further treatment of the effluent, because the statutes of the State of Maryland require rather high bacterial efficiency. As a detailed description of the testing plant has already been published,[a] it is sufficient to state that a small section of the city was sewered and that sewage amount-

[a] Eng. News, vol. 57, 1907, p. 235.

ing to about 50,000 gallons a day was brought to the plant and treated by a system comprising a grit chamber, a septic tank, trickling filters, and sedimentation tanks. Trickling filters of several depths and sizes of material are employed. The sewage is rather stronger than ordinary city sewage and is very fresh. The effluent used in the disinfection studies came from a filter 12 feet deep, built of crushed stone ranging in size from 0.5 inch to 1.5 inches. The rate of filtration fluctuated with the flow of sewage, but it averaged about 3,000,000 gallons an acre a day. The effluent was conducted to a sedimentation basin designed to give a two hours' flow. The disinfectant employed throughout this investigation was chloride of lime, dissolved and added to the effluent in practically the same manner as at Boston, as the effluent left the filter drain. The disinfecting solution and the effluent mixed during the short flow through a pipe to the sedimentation basin.

Monthly averages of the analyses of this effluent as it left the filter and after disinfection and sedimentation are given in Table 27.

TABLE 27.—*Chemical analyses of trickling-filter effluent at Baltimore before and after disinfection with chloride of lime and sedimentation: monthly averages.*

[Parts per million.]

INITIAL.

Month.	Suspended solids.		Organic matter.		Nitrogen as—			Oxygen consumed.[a]
	Total.	Loss on ignition.	Total.	Solids.	Free ammonia.	Nitrites.	Nitrates.	
1908.								
January	56	35	8.3	5.9	7.4	0.48	17	16
February	38	25	8.0	6.8	6.8	.13	17	17
March	53	31	8.9	7.5	5.5	.30	19	16
April	42	28	10.0	9.0	7.5	.08	21	18
June	33	21	7.0	6.5	4.0	.40	20	13
Average	45	28	8.4	7.1	6.2	.28	19	16

FINAL.

1908.								
January	38	26	8.5	6.2	7.2	0.49	16	15
February	25	17	6.8	5.8	6.8	.12	17	17
March	26	17	7.9	7.1	5.5	.19	20	15
April	34	20	9.6	7.6	7.9	.08	22	18
June	21	16	7.0	6.5	4.0	.25	20	13
Average	29	19	8.0	6.6	6.3	.23	19	16

[a] Thirty-minute boiling method.

Initial and final bacteriological samples were collected as usual. Bacterial counts were made three times a day for five days each week and twice on Saturday. *B. coli* determinations were made twice daily. The results are shown in Tables 28, 29, and 30. Table 28

gives the average weekly results; Table 29 shows the relation between the removal of bacteria in individual samples and the average removal; Table 30 indicates the relation between the number of bacteria in the individual samples and the average number.

TABLE 28.—*Disinfection of trickling-filter effluent with chloride of lime at Baltimore; weekly averages.*

Week ending—	Temperature.	Available chlorine (parts per million).		Total number of bacteria per cubic centimeter at 20° C.		Total number of bacteria per cubic centimeter at 37° C.		Number of acid formers per cubic centimeter at 37° C.		Number of B. coli per cubic centimeter.[a]	
		Initial.	Final.	Initial.	Final.	Initial.	Final.	Initial.	Final.	Initial.	Final.
1908.	° F.										
Jan. 4	50	3.5	.....	170,000	1,600	70,000	600	8,000	107	3,800	59
11	45	2.0	.....	90,000	6,500	5,500	200	3,000	58	1,700	380
18	48	1.9	.....	120,000	3,300	3,100	250	2,200	165	3,400	240
25	47	2.0	.....	160,000	1,900	2,000	95	900	8	1,300	45
Feb. 1	40	2.6	1.3	120,000	2,200	1,900	73	950	4	2,000	490
8	43	2.5	1.1	70,000	4,100	1,000	70	400	4	600	470
15	46	0.94	0.1	80,000	11,000	1,500	400	700	90	440	330
22	45	1.4	0.4	65,000	20,000	4,000	440	3,000	180	750	70
29	45	1.5	0.4	100,000	4,600	3,000	100	1,100	17	2,400	210
Mar. 7	46	2.0	0.6	80,000	1,000	1,400	80	900	2	1,600	150
14	47	1.7	0.4	80,000	1,700	1,000	60	500	5	1,400	180
21	49	2.0	0.4	100,000	1,300	1,100	80	600	15	2,600	180
28	52	2.1	0.3	150,000	1,700	2,400	160	1,500	3	800	210
Apr. 4	50	1.7	0.4	120,000	1,800	4,100	120	2,100	10	2,100	220
11	55	2.6	1.1	140,000	1,100	2,800	70	1,900	2	3,700	39
18	54	2.2	0.6	120,000	2,500	13,000	110	3,600	25	5,500	55
25	56	2.6	0.3	120,000	2,100	18,000	350	7,000	110	2,200	200
May 2	58	3.1	.....	130,000	1,200	3,500	110	2,400	3	1,400	130
9	56	2.8	1.0	160,000	2,300	2,200	70	1,600	9	1,800	43
June 13	66	2.3	0.4	120,000	17,000	21,000	3,600	9,500	[b]730	600	100
20	67	2.3	0.8	115,000	1,300	1,800	440	300	18	3,000	300
27	67	1.9	0.1	190,000	3,700	2,900	1,100	430	0	800	400
Average	51	2.2	0.6	120,000	4,300	7,500	390	2,400	70	2,000	200

[a] Jackson bile media used.

[b] High average due to one count of 8,000.

TABLE 29.—*Relation between individual tests of bacterial removal and the average result at Baltimore.*

Per cent of total tests.[a]	Per cent of bacterial removal.	
	Not less than—	Less than—
69	98	100
14	96	98
6	94	96
0	92	94
2	90	92
2	85	90
4	75	85
1	65	75
1	40	65
1	..	40
Total, 100.	Average, 95.5.	

[a] Total number of tests, 255.

TABLE 30.—*Relation between individual bacterial counts and the average result at Baltimore.*

Per cent of total tests.[a]	Number of bacteria per cubic centimeter.	
	Not less than—	Less than—
36	100	1,000
35	1,000	2,000
8	2,000	3,000
3	3,000	4,000
4	4,000	5,000
2	5,000	6,000
2	6,000	8,000
3	8,000	10,000
7	10,000	.....
Total, 100.	Average, 4,300.	

[a] Total number of tests, 255.

The average of the individual bacterial removals is 95.5 per cent. The per cent removal calculated from the average numbers in Table 28 is 96.6 per cent. The average efficiency, as in the Boston experiments, may be expressed in the latter form with sufficient accuracy, and this shorter method is employed in the other bacterial computations, by which the efficiencies in Table 31 were obtained.

TABLE 31.—*Average bacterial removal during the disinfection of trickling-filter effluent at Baltimore.*

	Per cent.
Total bacteria at 20° C	96.6
Total bacteria at 37° C	94.9
Acid formers at 37° C	97.0
B. coli[a]	90.0

The average results agree practically with those obtained at Boston. The trickling-filter effluent at Baltimore was of better quality than that at Boston and less chlorine was used. The average amount of available chlorine was 2.2 parts per million, as compared with 3.4 parts at Boston. Though the average reduction of total bacteria at both places was practically the same, the variations were greater at Baltimore, and they indicate that a somewhat greater amount of chlorine would materially improve the results. It is probable that three parts per million of available chlorine are best for treating this effluent. The *B. coli* results are not in harmony with the rest of the figures. In all the work at other places the removal of *B. coli* has been without exception better than the removal of the total organisms. Soon after the beginning of the Baltimore studies it was noticed that the removal of *B. coli*, as indicated by the bile test, was far less perfect than the general results, but efforts to discover the cause of the discrepancy were only partly

[a] Jackson bile media used.

successful. Complete identification of *B. coli* was carried out for a period, and the results seem to indicate that many of the positive tests after disinfection are due to the presence of an organism other than *B. coli,* which fermented the bile medium. Similar atypical results were obtained in the initial samples, but not in such large proportion. The evidence of other work under the direction of the author indicates that in these experiments the removal of *B. coli* is better shown by the removal of acid-forming bacteria than by the bile test. The results as a whole demonstrate the entire feasibility of the process and the possibility of obtaining practical disinfection at a reasonable cost.

COMPARATIVE GERMICIDAL EFFICIENCIES OF CHLORINE AND SOME OF ITS COMPOUNDS.

Only a small amount of accurate data was at hand for the comparison of the germicidal efficiency of chlorine in its various forms. Accordingly, three series of comparative tests were made upon trickling-filter effluents for the purpose of obtaining such information. The results of these studies are collated in Table 32, each figure of which is the average of from three to twelve tests reduced to a uniform basis of one million initial bacteria per cubic centimeter.

TABLE 32.—*Relative germicidal properties of chlorine and some of its compounds.*

[All numbers converted to a uniform basis of 1,000,000 initial bacteria per cubic centimeter.]

Series.	Source of chlorine.	Available chlorine (in parts per million).	Total number of remaining bacteria per cubic centimeter.		
			At end of 30 minutes.	At end of 1 hour.	At end of 2 hours.
I	Free chlorine	3	650	390	280
	Sodium hypochlorite	3	500	270	230
	Potassium hypochlorite	3	410	260	280
	Potassium chlorate	3	800,000	900,000	1,000,000
	Potassium perchlorate	3	750,000	1,400,000	1,800,000
II	Free chlorine	2	17,000	13,000	17,000
	Sodium hypochlorite[a]	2	15,000	6,000	6,000
	....do.[b]	2	4,600	2,100	3,400
III	Free chlorine	2	19,000	18,000	23,000
	Sodium hydroxide and chlorine[c]	2	23,000	14,000	19,000
	....do.[d]	2	22,000	12,000	18,000
	....do.[e]	2	23,000	9,000	10,000
	....do.[f]	2	19,000	7,500	8,000

[a] Electrolytic.
[b] From bleaching powder.
[c] Chlorine added thirty minutes after the hydroxide.
[d] Chlorine added twenty minutes after the hydroxide.
[e] Chlorine added ten minutes after the hydroxide.
[f] Chlorine added with hydroxide.

In series I comparison is made of free gaseous chlorine generated electrolytically, sodium hypochlorite, and potassium hypochlorite. Potassium chlorate and potassium perchlorate are also included, because they are formed in many direct electrolytic processes. The available chlorine of the two latter compounds is taken in an elec-

trolytic equivalent sense, and would be better expressed by the term "oxidizing power." Three parts per million of available chlorine were used in all the tests of series I.

In series II comparison is made of free gaseous chlorine, potassium hypochlorite prepared from bleaching powder, and the same compound electrolytically prepared by the recombination of the products of the electrolytic cell. In this and in the next series two parts per million of available chlorine were used, because it was found that comparisons are more readily made where the disinfection is not so nearly complete.

In series III free chlorine was again used and was compared with the electrolytic hypochlorite. In this set of experiments, however, the hypochlorite was made in the sewage by adding separately the chlorine water and the sodium hydroxide. In three sets of tests the addition of the hydroxide preceded that of the chlorine by ten, twenty, and thirty minutes, respectively. The object of this procedure is to determine whether the caustic soda and the gaseous chlorine possess separately better penetrating powers than the hypochlorite does. If such were the case, formation of the hypochlorite within the solid particles of the sewage might result in more complete disinfection than could otherwise be obtained.

The results indicate plainly that hypochlorites are the most efficient germicides. Gaseous chlorine is almost as good, but in each series the free chlorine is somewhat inferior to the hypochlorite. Chlorates and perchlorates have almost no value in disinfection. The formation of these compounds in the electrolytic cell is, therefore, a total waste of energy, and should be prevented as far as possible. Production of these compounds explains in large measure the inefficiency of hypochlorite cells. Hypochlorites made electrolytically are slightly inferior to the market product, but this difference would probably be inappreciable in large-scale tests, where the conditions under which the hypochlorites are prepared are more nearly those of commercial practice. Hypochlorites of different bases evidently have the same value; the results obtained with the sodium and the potassium salts are practically identical and are similar to those obtained in practice with the calcium salt. The claim that the magnesium compound is more efficient than the calcium compound was not investigated. Hypochlorites can be made advantageously by mixing dilute solutions of free chlorine and sodium hydroxide, the products of the electrolytic cell, but the mixing should take place either in the sewage or in cold dilute solution, as otherwise chlorates and perchlorates will be formed; if the hydroxide is added a short time before the chlorine, it is removed from the solution, leaving free chlorine uncombined and leading to a more rapid exhaustion of the available chlorine.

These tests have an interesting bearing on the question of the exhaustion of the chlorine. It appears that the chlorine attacks the organic matter and the bacteria simultaneously, but that its effect on the former is a direct function of its concentration, while its germicidal effect does not bear such exact relation. If these are the true conditions, the successive addition of small portions of chlorine, or what amounts to the same thing, the addition of a substance that yields chlorine slowly, prevents the rapid reduction of the chlorine by the organic matter and prolongs the time of contact with the bacteria. In series III, Table 33, more or less of the hydrate was consumed in saponification before the chlorine was added, the amount so removed depending on the time that elapsed between the addition of the hydroxide and the addition of the chlorine. The first set of series III, therefore, represents the action of free chlorine, and the last set the action of hypochlorite, with the intermediate tests representing different proportions of the two substances. The progressive nature of the final results indicates strongly the necessity of having the chlorine combined in such form that its action on organic matter is retarded. The same effect is shown in the work on crude sewage described on pages 37–51. In the experiments reported in Table 22 decidedly better results were obtained by adding the hypochlorite in four equal portions at hourly intervals than by adding the entire amount at once. In practice the effluent to be treated should never be acid in reaction; it is probable that the addition of lime would still further decrease the rate of decomposition of the hypochlorite and increase its bactericidal efficiency.

EFFECT OF CALCIUM HYPOCHLORITE ON COLON AND TYPHOID BACILLI.

The colon bacillus has been employed in this and in other work as a convenient test organism with which to measure the efficiency of the disinfection process. For obvious reasons experiments on a large scale with the typhoid bacillus are out of the question. Consequently, a comparison was made between the relative resistance of the typhoid and the colon bacilli under controllable conditions, with the idea that in practice the effect of the disinfection process on the former could be measured by its effect on the latter. Emulsions of the two organisms in tap water were treated with hypochlorite solution, and the parallel tests with the two species were made at the same time and were kept as nearly alike as possible. The number of bacteria per cubic centimeter was determined at the end of twenty, forty, and sixty minutes, and two, four, and eighteen hours, and twelve tests of each kind were made in the same manner. The available chlorine ranged from 3.5 to 6 parts per million, averaging 5 parts. The results of the individual tests varied greatly from day to day, because,

no doubt, of difference in the character of the growths and in the amounts of organic matter introduced with the organisms. Yet the average figures obtained from these twelve sets of tests probably give a fair basis for estimating the comparative resistance of the two organisms to the disinfectant. The per cent removal has been calculated and the average results are presented in Table 33.

TABLE 33.—*Comparative resistance to calcium hypochlorite of B. typhi and B. coli in aqueous emulsion.*[a]

Tests made at end of—	Removal of bacteria (per cent).	
	B. typhi.	B. coli.
20 minutes	90.5	92.0
40 minutes	98.2	98.0
1 hour	99.45	99.53
2 hours	99.60	99.70
4 hours	99.92	99.96
18 hours	99.99+	99.99+

[a] Average available chlorine, 5.0 parts per million.

The slight differences shown by the experiments on the two organisms may be attributed to experimental variations. The work is not conclusive because other strains of organisms might have yielded different results, but it indicates in a general way that *B. coli* may reasonably be regarded as test organisms in disinfection work and that the process may be expected to destroy typhoid organisms present at least as thoroughly.

It is interesting also to note that the per cent removal of *B. coli* after four hours is about the same as that recorded in the experimental disinfection of crude sewage; namely, 99.96 per cent as compared with 99.93 per cent.

PRACTICAL APPLICATIONS AND COSTS OF DISINFECTION.

The experiments that have been described were sufficiently prolonged and varied in their scope to justify the application of the chloride of lime treatment to practical disinfection on a large scale. It is not possible, however, to draw general conclusions regarding the amount of chlorine necessary for the disinfection of effluents, much less of crude sewage, because the dose is determined largely by the character of the organic and reducing matters contained in the sewage or the effluent. But the investigations have shown what may be accomplished under several conditions and they have established certain probable maximum amounts of chlorine for particular classes of sewage and effluents. They have demonstrated, for example, that trickling-filter effluents similar to those tested may be satisfactorily

disinfected with three or four parts per million of available chlorine, and that such quantity will usually be sufficient to effect the removal of 95 per cent or more of the total bacteria in the effluent. If the effluent should contain only 25 per cent of the original sewage bacteria, the whole purification process would result in a removal of 98.8 per cent of the total number of bacteria. The per cent removal of *B. coli* and of typhoid organisms will be at least as high if not higher. Crude Boston sewage can be disinfected to about the same extent with from four to six parts per million of available chlorine. It may reasonably be inferred, therefore, that five parts per million of chlorine represent the maximum concentration that would ever be necessary for the disinfection of a fairly stable effluent, since no such effluent would contain as much oxidizable organic matter as the crude sewage that is treated. The septic sewage of Red Bank probably represents a maximum condition for crude sewage, because its high content of hydrogen sulphide and other oxidizable matters would probably never be exceeded in crude sewage, or at least in sewage from American cities. The disinfection of crude sewage, therefore, would require four to twelve parts per million, of available chlorine, depending on the character of the sewage and its content of oxidizable matters. It will probably be undesirable to treat septic sewage, but if such sewage should be treated, from ten to fifteen parts of chlorine, or perhaps more, would be necessary. The extreme variability of the composition of septic sewage makes it almost impossible to fix a maximum limit for the amount of hypochlorite. The amount of disinfectant required in any plant would necessarily be determined before final adoption of the plan, but these estimates will serve as useful guides, and the limits assigned include the majority of probable conditions.

No data have been obtained with effluents of higher degree of purity than those from trickling filters. The general conclusions from the work have been that the disinfectant action is a function of the chlorine concentration and of the time of contact, and that the time is determined largely by the rate at which the chlorine is consumed by the organic matter. Effluents of a better grade would probably require the same amount of chlorine, if the disinfection were to be accomplished within two hours. In the effluents with which experiments were made, the chlorine was practically consumed in two hours, but in a purer effluent chlorine would probably be left. This indicates that somewhat smaller quantities could be used with longer storage periods. A point is soon reached, however, beyond which the cost of storage is greater than the saving in disinfectant. Effluents of high degree of purity could probably be disinfected with one part of available chlorine, but a contact period of at least five hours would be required for satisfactory removal of the bacteria. One part is

probably the minimum amount of chlorine that can be used, as the necessary time of contact increases very rapidly with decreasing concentration of chlorine.

One of the most important practical points that has been developed is the relation between organic matter, time of contact, and amount of chlorine necessary. Obviously a definite concentration of chlorine acting for a given time will bring about a definite result independent of the nature of the solution. If, however, chlorine is being consumed by the solution itself a greater amount will have to added at first in order to maintain the same average concentration. On the other hand, longer periods of contact with lower chlorine concentration are possible with the better grades of effluent. The experiments with various kinds of sewage make it possible to formulate a crude rule, which may be stated as follows: The product of the initial concentration multiplied by the time in hours required for complete reduction of the available chlorine should be about five for satisfactory disinfection, except that the contact period must not be less than half an hour in any case.

It is possible to fix within narrow limits the cost of chlorine disinfection. The cost is determined chiefly by the concentration of chlorine necessary and the related factor of contact period, and secondarily by the size of the plant. The unit used in the following summary of costs is a plant with a daily flow of 5,000,000 gallons of sewage, such a plant being the smallest that would require the entire time of an attendant, a part of whose salary may legitimately be charged to disinfection. On larger works the labor costs would increase proportionately, and on smaller works arrangements would naturally be made by which the plant could receive proper attention in connection with the regular work of the sewer or street department. The price of bleaching powder has been estimated at $24 a ton delivered at the plant; it is quoted at from $22 to $25, and a price as low as $20 is obtained on large orders by certain paper mills. The price taken is, therefore, sufficiently high to cover the cost of the moderate-sized shipments that would be required for a 5,000,000-gallon plant. A 50,000,000-gallon plant could obtain its bleaching powder for at least 10 per cent less. This bleaching powder would contain over 35 per cent available chlorine, but in order to allow for waste 33 per cent has been taken as the average figure. Labor is computed at $2 for an eight-hour day. Two hours a day—an ample allowance—are reckoned for the care of a 5,000,000-gallon disinfecting plant using 5 parts or less of chlorine. For over 5 parts the time would increase proportionately. Interest, depreciation, and other fixed charges are computed as 6 per cent of the cost of the additional works made necessary by the disinfection treatment; as the con-

struction is chiefly masonry, but little depreciation need be allowed. In certain projects sedimentation tanks would already be available, so that the application of disinfection would not require the construction of storage tanks. For this reason the item storage tanks has been separated from the other fixed charges that include 6 per cent of the cost of mixing tanks and storage tanks for the solution, pumps, piping and connections, and suitable housing. In handling the chemicals for a plant requiring 3 parts per million or more of chlorine, some form of power mixer would be economical, and that item has been estimated. In small plants the mixture of bleaching powder and water would be settled and the solution decanted, but in the larger works the whole mixture would be used, and it would require constant stirring. The increased power item would be more than counterbalanced by the saving in tank construction. Table 34 contains a summary of the cost estimates for chlorine concentrations from 1 to 15 parts per million.

TABLE 34.—*Estimates of the cost of maintenance and operation of a plant for disinfecting sewage or effluent with chloride of lime, based on a capacity of 5,000,000 gallons a day.*

Available chlorine in parts per million).	Time of contact (in hours).	Cost per million gallons.					
		Storage tanks.	Other fixed charges.	Bleaching powder.	Labor.	Power.	Total.
1	5.0	$0.10	$0.02	$0.30	$0.10	.....	$0.52
2	2.5	.05	.04	.60	.10	.....	.79
3	1.6	.04	.05	.90	.10	$0.02	1.11
4	1.2	.03	.07	1.20	.10	.02	1.42
5	.8	.03	.08	1.50	.10	.03	1.74
10	.5	.02	.16	3.00	.15	.06	3.39
15	.5	.02	.24	4.50	.20	.09	5.05

The estimates made for a 5,000,000-million gallon unit can be safely applied to larger works, and they are applicable within reasonable limits to small works that are properly managed. The cost of the tanks and of covering them would become proportionately cheaper with increased size, but this saving would be offset by the advisability of better construction and architectural embellishment. The saving due to decreased price of bleaching powder for a 50,000,000-gallon plant, using 3 parts per million of chlorine, would be about $4.50 a day, which would approximately pay for the additional chemical and bacteriological control required by a plant of such size. On very large works labor items would not increase proportionately, because most of the work would be done by machinery.

In an earlier paper[a] the opinion was expressed that the expense might be considerably reduced and efficiency increased by using

[a] Phelps, E. B., and Carpenter, W. T., The sterilization of sewage filter effluents: Tech. Quart., vol. 19, 1906, p. 382; Contr. from Sanitary Research Lab., vol. 4, 1908.

electrolytic chlorine produced at the disposal works instead of bleaching powder. The relation of electrolytic processes to sewage disinfection is still unsettled, but a study of the present possibilities of such processes and experimental work with the McDonald cell and with small cells of special design have indicated that the margin of cost between the alternative methods is so slight that it hardly justifies the additional effort and the uncertainty involved in the establishment of an electrolytic plant. A brief discussion of recent developments in this field will show the reasons for this conclusion. Two general types of electrolytic process are available, in both of which the electric current is passed through a solution of sodium chloride, chlorine being liberated at one electrode and caustic soda at the other. In one type these products are allowed to recombine, forming sodium hypochlorite and certain other compounds. In the other type the products are removed from the cell as quickly as possible, the aim being to prevent their recombination. Numerous processes of the first kind have been developed, of which the Hermite and Woolfe processes have already been mentioned. The commercial preparation, called "Chloros," is made in this way. The most recent, and probably the most improved, cell of this type has recently been described by Digby and Shenton.[a] The reaction by which the hypochlorite is produced from chlorine and caustic soda in cold dilute solution is:

$$(1)\ 2\ NaOH + 2Cl = NaOCl + NaCl + H_2O.$$

In the paper just cited Digby proposes the reaction,

$$(2)\ NaOH + Cl = NaOCl + H.$$

He bases his view on the observation that the electro-chemical efficiency of the cell is over 50 per cent. Aside from the obvious impossibility that a reaction can produce at one and the same time nascent hydrogen and a strong oxidizing agent, it is apparent that reaction (1), if it were carried out completely, would yield a product containing not 50, but 100 per cent of the available chlorine initially present. The conception that this reaction represents a loss of half the available chlorine is due apparently to a mistaken idea of the term available chlorine, which, as has been explained on page 18, is really a misnomer. The fact is that the oxidizing power, or the available chlorine as ordinarily determined, of the products of reaction (1) is equivalent to twice the chlorine of the hypochlorite, or to the total chlorine present. There is, therefore, no apparent basis for the reaction proposed by Digby, which would yield twice as much available chlorine as the amount allowed by the law of electro-chemical equivalents. The reactions of equation (1) are complete only in cold

[a] Digby, W. P., and Shenton, H. C. H., Surveyor, vol. 30, 1906, p. 653.

dilute solutions. If the solution is hot or if it is concentrated chlorates and perchlorates are produced simultaneously. It is for this reason that the disinfectant value of these two sets of compounds was determined in an earlier part of the present investigation. It was found that they possess practically no disinfecting power and that their production in the cell represents a loss of energy. Economy in electric current demands strong salt solutions and high current densities with consequent heating of the electrolyte. Electrical efficiency is, therefore, opposed to chemical efficiency, and the problem in designing cells of this type is to balance the two efficiencies in the most economical manner. The electro-chemical equivalent of a current of one ampere is 1.32 grams an hour of chlorine, and this equivalent is not modified by the voltage. However, as the total energy employed in a process determines its cost, it is necessary to consider voltage as well as current in discussing electrolysis. In any electrolytic reaction there is a definite minimum voltage required for carrying out the reaction, and this can be computed from thermal considerations as follows: The complete reaction in the cell before the recombination of the hydroxide and the chlorine may be written,

$$NaCl + H_2O = NaOH + H + Cl.$$

Substituting the heats of formation of these compounds gives

$$964 + 684 = 1118 + x, \text{ whence}$$

$$x = 530 \text{ calories (K)}.$$

Here x is the heat required by the reaction, expressed in calories (K) per gram-equivalent of the reacting substances, and its value is 530 calories. One gram-equivalent of substance is transformed with the passage of 96,540 coulombs of electricity, and one coulomb transferred under a difference of potential of one volt has an energy equivalent to 0.00241 calories. Therefore, one electro-chemical equivalent of current at a difference of potential of one volt has a heat value of 96,540 multiplied by 0.00241, or 232.7 calories. Consequently the voltage required to effect the desired reaction, which calls for a heat absorption of 530 calories per equivalent, is 530 divided by 232.7, or 2.28 volts. This is the minimum voltage with which the reaction can take place, and efficiency calculations to an energy basis must be referred to this voltage. At a difference of potential of 2.28 volts, one kilowatt gives 439 amperes, so that an output of 579 grams of chlorine per kilowatt-hour represents a process of 100 per cent efficiency on both a current and an energy basis. In practice a current at a tension of at least 4.5 volts is usually found necessary, even with strong solutions of salt and with electrodes placed as near together as possible. This factor alone reduces the energy efficiency to 55 per cent with perfect current efficiency. The

current efficiency depends especially on the design of the cell. If there are no complicating secondary reactions during the recombination of the products it approaches 100 per cent very closely, and this is also the case in the most improved design of chlorine cell in which recombination does not take place. It is clear that the production of hypochlorite in one operation within the cell is not economical, and a review of the available information and a laboratory study of various hypochlorite cells have led to the conclusion that cells of that type can not be expected to yield much more than one-half the available chlorine that can be obtained from the same electric current by means of direct chlorine cells.

Direct chlorine cells have been developed to a high degree of efficiency, and this is the type of cell which has been considered in the present studies of sewage disinfection. The McDonald cell, which was used to some extent in this work, is giving in a regular installation in a large paper mill a current efficiency of over 80 per cent at 4.5 volts, making the total energy efficiency over 43 per cent. The most recent development is the Townsend cell, for which current efficiencies exceeding 98 per cent are claimed at a tension of 5 volts or more. The special feature of the Townsend cell is an arrangement by means of which the caustic liquor drops into a bath of oil as soon as it is formed, a step that prevents recombination. In spite of the high efficiency of such cells, it is not practicable to employ them in sewage work on account of the small margin between the market cost of chlorine and the cost of its manufacture electrolytically. This condition is due to the fact that the demand for caustic soda is so much greater than that for chlorine that the chlorine is to a certain extent a by-product and can be made into bleaching powder and sold at low cost. On the other hand, the manufacture of small amounts of caustic liquor at the disposal works does not warrant the installation of the necessary machinery for the production of pure caustic soda; consequently, without a market for this by-product, the cost of the chlorine would be the entire cost of the operation. In addition, a skilled chemical engineer who would be required would increase the cost per million gallons much more in a small plant than in a large one, while the uncertainty of the process and the increased responsibility on the sewage works both offset any slight advantage in cost which might appear in favor of the electrolytic plant. It has also been made clear in the present studies that the use of free chlorine, as contemplated in the earlier plan, is not economical and that some base should be provided for the preparation of hypochlorite. This base might be the caustic soda yielded by the process, or if a market for that by-product were available, lime could be used.

For the reasons outlined, therefore, this investigation of the possibilities of the electrolytic processes indicates that, contrary to earlier

views, such processes are not well adapted at the present time to sewage disinfection. Nor does it seem probable that hypochlorite from cells in which the products are allowed to recombine within the cell will ever be able to replace ordinary bleaching powder.

CONCLUSION.

The main reason for disinfecting sewage lies in the probable effect of discharging pathogenic bacteria into lakes, rivers, and harbors. Any such discharge is obnoxious to the sanitarian, and when the practice of computing the cost of typhoid-fever epidemics becomes more general the cost of disinfecting sewage will not appear excessive. At present, however, the demand for sewage disinfection is confined to two conditions, namely, the possible pollution of water supplies and of shellfish beds. It has not yet been decided upon whom the responsibility rests for protecting domestic water supplies. The sanitarian recommends that rivers be kept as clean as possible and that water be filtered, but in practice distinction is made between supplies which are filtered before use and those which are not, and complete disinfection of sewage that enters streams from which supplies of the first kind are derived is still regarded as an unreasonable demand. The concensus of competent opinion requires at least, however, that, if an effluent is discharged within the region of important shellfish beds or into a stream which is used as a source of domestic water supply without filtration, such effluent shall be free from pathogenic germs. Improved standards in sanitation and improved methods of disinfection will both operate to increase these minimum requirements, but in the meantime a thorough knowledge of disinfection methods and experimentation on the improvement and the cheapening of such methods will do much to hasten their general adoption. Slow sand filtration removes bacteria in a satisfactory manner and almost totally eliminates organic matter. Under certain conditions such a result is highly desirable, but the method is comparatively costly, especially in the larger communities, and it is practically out of the question in many sections of the country.

Chemical disinfection offers a means whereby a reasonable bacterial purification may be accomplished without complete purification of the organic matter. It is in no sense a substitute for sewage purification as ordinarily understood, for, though the application of chlorine compounds to an effluent oxidizes the organic matter in it to some extent and thereby increases its stability, such improvement is only incidental. It is not in anyway comparable with the cost of treatment, and it would be unwise to attempt to obtain stability in such manner. Incidentally, however, the advantages of this increased stability are obtained, and it is probable that rapid sewage filters

may be worked at somewhat higher rates and with less margin for safe operation where chlorine treatment is employed as a finishing process. Under certain conditions it may be found desirable to effect bacterial removal without organic stability; along the seacoast and possibly along some great rivers of the Middle West the dilution factor is sufficienty high to preclude the danger of physical nuisance. Under other conditions the production of a stable effluent without regard to the amount of organic matter discharged may suffice; under others the removal of suspended matter may be of prime importance. Due consideration should be given in any particular process to the character of the organic matter in the effluent, and further treatment is advisable, not only where the discharge produces, or threatens to produce, an actual physical nuisance, but wherever the self-purifying powers of the stream will be appreciably drawn upon. In other words, stability is demanded in all effluents, unless the dilution is very great, not only in relation to the local discharge, but also in relation to all the sewage or effluent that the body of water in question may receive. This much is demanded from the standpoint of physical pollution alone. If, therefore, bacterial removal is also essential, disinfection is particularly satisfactory as a finishing process, because it can now be conducted at far less cost than the cheapest form of supplementary sand filtration.

Comparison on a cost basis of the methods of chemical disinfection makes it apparent that chlorine in some form is the most efficient agent, though it must be admitted that the possibilities of heat and of certain organic compounds have not received adequate investigation. Calcium hypochlorite, or commercial bleaching powder, is by far the most satisfactory chlorine compound available. It has greater germicidal efficiency than equivalent amounts of free gaseous chlorine, chlorates, or perchlorates. It is equaled in efficiency by potassium and sodium hypochlorites, the products of certain electrolytic cells. The electrolytic production of hypochlorites or of free chlorine is not a satisfactory source of the disinfectant. The cost of such manufacture, on a scale necessarily small even at the larger sewage-disposal works, is at present so little below the cost of bleaching powder that no safe margin is left to cover the additional responsibility and uncertainty that are involved. Improved processes of manufacture may alter conditions somewhat, but the highest possible working efficiency and the cheapest power would not sufficiently reduce the costs to alter these general conclusions.

The application of 3 parts per million of available chlorine in the form of bleaching powder to a trickling-filter effluent similar to those on which experiments were made effects satisfactory disinfection. The removal of bacteria from the effluent averages over 95 per cent, making the removal for the whole purification process 98 to 99 per

cent of the number in the crude sewage. The cost of disinfection ranges from $1 to $1.50 per million gallons of sewage, depending chiefly on the size of the plant. Effluents of higher degrees of purity can be disinfected at still lower cost. Five parts per million probably represents the maximum amount of chlorine required for the treatment of trickling-filter effluents of poorer quality. The results obtained with the amounts of disinfectant that are specified do not, of course, amount to complete sterilization, but they may reasonably be called "practical disinfection." Considerable additional cost is required to improve them but slightly.

The disinfection of crude sewage to the same final condition requires the removal of over 98 per cent of its total bacteria. This may be accomplished by the application of from 5 to 10 parts per million of available chlorine, the amount depending on the character of the sewage. Such disinfection costs from $1.50 to $3.50 per million gallons.

The disinfection of septic sewage requires the application of from 10 to 15 parts per million of available chlorine. If no further purification is required than that given by septic action and by disinfection, it is advantageous to reverse the processes by disinfecting the crude sewage before it enters the tank. The resulting development of saprophytes within the tank has no sanitary significance, and it is doubtless of great advantage in the subsequent purification of the organic matter in the stream.

The removal of *B. coli* is usually somewhat more complete than that of the total organisms. Under the conditions of a laboratory experiment, the results of hypochlorite disinfection on typhoid and colon bacilli in tap water were identical. It seems reasonable to assume, therefore, that the viability of the typhoid organism under working conditions in practical sewage disinfection is at least no greater than that of the colon bacillus and no greater than that of the sewage bacteria as a whole. Consequently the disinfection results obtained with total bacteria may, in the case of chlorine disinfection at least, be referred directly to the typhoid bacillus with assurance of reasonable accuracy.

The results obtained in this investigation are so much more favorable than any results that have been reported for similar work that comment on their accuracy and general applicability seems justifiable. The more important portions of the work have been practically duplicated under as diverse conditions as possible and by different workers. There is no apparent reason for believing that the results are not of general applicability. The reactions involved are particularly free from interference on the part of the mineral constituents of normal sewage, a condition which has not been found where copper has been used as the disinfectant. The satisfactory results

in the present work are largely due to the fact that many little difficulties inherent in new processes have been overcome by continuous work extending over considerable periods of time, and in particular to the fact that the experiments were made part of permanent laboratory routine and were free from temporary and special characteristics which usually involve discontinuity and interruption. This routine continued week after week without interruption and without undue attention—in fact, just as it would naturally go on in practice. It is believed that the results represent what may be accomplished in practice and that they can be duplicated under working conditions on any scale which may be desirable.

PUTRESCIBILITY AND STABILITY OF SEWAGE EFFLUENTS.[a]

INTRODUCTION.

The development of modern rapid processes of sewage treatment, involving the use of coarse material, has resulted in a somewhat changed conception of the functions of sewage disposal, while the general introduction of contact and trickling filters in the newer and larger works has made it necessary to examine methods of sewage analysis from a new viewpoint. Certain hitherto important features of the analysis have assumed comparatively unimportant rôles, and new determinations have been developed on which the chief reliance is now placed. In the older methods of sewage purification, almost complete removal of organic matter and oxidation of the nitrogen were obtained, and the analytical methods employed in the control of such plants were designed to test their efficiency in accomplishing these ends. Consequently the determination of nitrogen in its different stages of oxidation and of organic matter in general were paramount. These determinations are only of minor importance in the practical control of modern rapid filters, where oxidation of nitrogen is incidental and removal of organic matter is but slight. Suspended solids, available oxygen, and the character of the effluent in reference to its stability now demand first consideration. As the production of a stable effluent is the primary function of such filters, the determination of stability becomes the most important analytical method in filter control. This point has been generally recognized, and incubation or putrescibility tests of one form or another are in general use, often at places where no further analyses are made. It unfortunately happens, however, that there are many different conceptions of what putrescibility really is and many different methods of determining it. Consequently statements of results lose much of their significance and comparisons are difficult or impossible. The present article is a review of the subject for the purpose of establishing the fundamental facts and of harmonizing current opinions. A method of determining stability, which has been in use by the writer for nearly three years, and a numerical method of expressing results, by which quantitative value is given to the test, are also presented.

[a] Investigation made at the sanitary research laboratory and sewage experiment station of the Massachusetts Institute of Technology.

PUTRESCIBILITY.

Putrescibility, as applied to organic matter in general, implies the ability of that matter to undergo offensive putrefactive decomposition. In a strict sense putrefaction is a term applied to nitrogenous matter only, though this is a popular rather than a logical conception. Exactly what constitutes offensive putrefactive decomposition in a sewage effluent is a matter on which opinions differ. Such decomposition is always anaerobic, and it is usually accompanied by the evolution of offensive odors. These two phenomena have, therefore, formed the basis of most putrescibility tests. Some criteria of putrefaction which have been employed are: (1) Development of offensive odors; (2) formation of black sediment; (3) reduction in the amount of dissolved oxygen; (4) loss of all dissolved oxygen; (5) loss of all available oxygen, including that of nitrates and nitrites; and (6) increase in the oxygen-consumed figure. Some of these tests are based on partial reduction of the available oxygen in the effluent; others depend on the complete reduction of the available oxygen and subsequent anaerobic fermentation. The tests most commonly employed belong to the latter group, depending on the production of odor or of hydrogen sulphide, blackening of the liquid, or reduction of organic dyes. The test which depends on an increase in the oxygen-consumed figure during incubation is also in that class, because anaerobic fermentation alone renders organic matter more readily oxidizable.

These two types of test illustrate two distinct points of view which should be clearly differentiated. An effluent may be regarded as being composed of a given mass of organic matter dissolved or suspended in a definite amount of water. The water contains also a definite amount of available oxygen in the form of free dissolved oxygen, nitrites, nitrates, and possibly of other compounds. All the organic matter is oxidizable to some extent, and to that extent it serves as bacterial food. The greater the amount of organic matter and the greater its oxidizability, the greater is the absorption of oxygen from the medium. Consequently a reduction of available oxygen in the effluent during incubation is a measure both of the amount of organic matter present and of its capability of oxidation. As a small amount of readily oxidizable matter has the same effect on the result as a larger amount of more stable matter, a test of this kind indicates whether or not the organic matter consumes oxygen; but it does not show whether or not the supply of available oxygen is sufficient to prevent the establishment of anaerobic conditions. This important question of the balance between the oxygen demanded by the organic matter and the oxygen available in the

liquid is taken into consideration by tests of the second kind mentioned, namely, those dependent on the establishment of anaerobic conditions. Such tests do not involve estimation of the amount and the kind of organic matter; indeed, organic matter which does not absorb any oxygen from the liquid under the conditions of an incubation test must be very highly oxidized; and, furthermore, most organic matter derived from sewage is putrescible in itself—that is, if it is stored by itself in the absence of oxygen, it undergoes putrefactive changes. The question at issue is not, however, whether the organic matter itself will putrefy, but whether the effluent as a whole will become so reduced in oxygen that putrefaction will become possible. In other words, it is simply a question of a balance between the available oxygen of the effluent and the oxygen which the organic matter will require during the incubation period. It would seem that the problem might readily be solved by determining this balance, but, unfortunately, it is not a simple matter, because the action involved is bacterial. Many attempts have been made to determine the oxygen balance analytically, but such tests answer only with very good and very bad effluents, for which an inspection of the sample would serve just as well. When there is doubt about the character of the effluent—the condition for which such information is of most value—all such analytical procedures have heretofore failed. It is evidently impossible to imitate with any degree of precision the bacterial activities that are involved. There remains, then, but one satisfactory expedient: To let the reaction proceed by itself and to note the result. But here also there are difficulties, because bacterial reactions of this sort are necessarily slow in reaching equilibrium, and the time required by a nicely balanced effluent is greater than can be allowed in routine work. Some arbitrary period of time, therefore, is usually adopted, and it is in respect to this factor that the confusion rises. If stability is to be considered a definite qualitative characteristic of an effluent, that characteristic should be determined by a test sufficiently prolonged to insure equilibrium, but such procedure is not feasible for obvious practical reasons, and it is not desirable, because it is not enough simply to know that the available oxygen is sufficient or insufficient to satisfy the demands of the bacteria that are working on the organic matter. If the available oxygen is sufficient, there is perfect stability—a definite condition; if it is insufficient, there is still stability in the quantitative sense—a relative stability determined by the relation of the available oxygen to the total amount of oxygen required by the organic matter for perfect stability. In practice the latter condition is the one usually encountered.

RELATIVE STABILITY.

DEFINITIONS.

The term putrescibility has had so many and so varied meanings in dictionaries, in popular parlance, and particularly in the minds of water chemists, that it is proposed to employ the word *stability* for that desirable quality which is the usual object of sewage purification—the transformation of the organic matter to such form that it is incapable of undergoing offensive putrefaction. This term has the added advantage of implying a positive characteristic that is acquired during purification, and it conveys a much more definite impression of the thing under discussion than the negative term *putrescibility*. A few more definitions are necessary in order to simplify the discussion. The time required to establish anaerobic conditions in an effluent which, on incubation in a closed bottle, is subject to bacterial activities producing such conditions may be called for brevity the *reducing time;* the total amount of oxygen initially present in the form of free dissolved oxygen, nitrites, nitrates, and possibly other combinations may be called *available oxygen;* the term oxygen required for equilibrium or simply *required oxygen* may be understood to express the total amount of oxygen which would be consumed by bacterial action in the effluent if the latter were supplied with an unlimited amount of oxygen and if the reaction were allowed to proceed to a condition of substantial equilibrium. An effluent of the character under discussion is not stable in the absolute sense, because its available oxygen is less than the oxygen required for equilibrium; but, of two such effluents, that one is obviously the better which contains the greater amount of available oxygen in proportion to its required oxygen. In other words, effluents of this class have a certain relative stability which is indicated by the ratio of the available oxygen to the required oxygen. This relative stability, as will be shown, can be measured by the time required to reach the anaërobic stage. The term *stability* without qualification is employed in this paper to describe that condition in which the available oxygen exceeds the required oxygen, and the term *relative stability* is used to indicate the character of the effluent in the sense suggested. A perfectly stable effluent, therefore, has a relative stability of 100 per cent.

It is apparent that time is an important element in stability tests, and that it is not compatible with the idea of relative stability to select an arbitrary period of time for establishing the line of demarcation between stability and putrescibility. It is obviously unfair to record one effluent as nonstable because it "holds up," or fails to putrefy, for only three days and to record another as stable

because it "holds up" for four days. A filter might deliver during one week an effluent that would fail to pass a four-day incubation test by a narrow margin and might deliver during the next week almost crude sewage for four days and a passable effluent for three. Obviously, the first week's run would be the better and should be so recorded; but, under the present practice in many places, all the samples during the first week would be putrescible and 40 per cent of those during the second week would be nonputrescible. The first requisite, therefore, in logical study of the problem is that the time required for an effluent to reach a condition of anaerobic decomposition shall be taken as an index of its relative stability. This time element is absolutely indispensable, and any test that is adopted for the determination of relative stability should be of such a character that the length of time required for the sample to reach a given anaërobic condition may be recorded.

ESTIMATION OF THE REDUCING TIME.

Many tests have been devised to determine whether or not an effluent is putrescible, and a review of the subject with the details of the methods proposed has been given elsewhere.[a] In any determination of the time required to exhaust the available oxygen in an effluent the following conditions must be fulfilled: (*a*) The sample must completely fill the bottle, the stopper of which must be tight and must not be removed during the test; (*b*) determinations must be made at a standard temperature; (*c*) observations must be made at least as frequently as once a day. If a test is employed which necessitates opening the bottle in order to observe the condition of the sample, one bottle must be incubated for each day that the effluent is under observation. This is true for any test which depends on a chemical determination of any constituent or which depends merely on the odor developed. Obviously such tests are not well adapted to the conditions heretofore stated. A simpler procedure is one in which the anaerobic condition can be detected by the appearance of the effluent without opening the bottle. The anaerobic fermentation that occurs immediately after the complete exhaustion of the oxygen is usually accompanied by a production of hydrogen sulphide. Consequently an indicator that is sensitive to hydrogen sulphide is advantageous in detecting the beginning of the anaërobic fermentation. Fortunately delicate indicators are available for this purpose, for certain organic dyes are readily reduced to corresponding leuco-compounds under anaerobic conditions. Methylene blue is an organic dye of this character, and it is reduced to its colorless leuco base by hydrogen sulphide, alkaline sulphides, and by the

[a] Phelps, E. B., and Winslow, C.-E. A., On the use of methylene blue in testing sewage effluents: Jour. Infectious Diseases, Suppl. No. 3, 1907, p. 1.

commercial reducers used in dyeing. Its employment for the study of stream pollution was first proposed by Spitta,[a] and it was later more thoroughly investigated by Spitta and Weldert [b] as a test for sewage effluents.

Methylene blue, or tetra-methyl-thionin chloride, is a commercial dye of complex constitution, having the empirical composition $C_{16}H_{18}N_5SCl$. Merck's medicinal preparation is pure and it is preferable to the commercial article for sewage work. It is an extremely sensitive indicator for hydrogen sulphide and other reducing bodies, being decolorized at once in the presence of even small traces; its decolorization by bacterial action has been studied by many observers, the principal of whom are cited by Spitta and Weldert.[c] The technique of its use in testing a sewage effluent is extremely simple. One cubic centimeter of a one-tenth per cent aqueous solution of the dye is added to the effluent in a glass-stoppered bottle of 250 cubic centimeters capacity, and the sample is then incubated either at 20° C. or at 37° C. The blue color of the solution remains practically unchanged till the available oxygen contained in it has been consumed and putrefactive conditions have been established. At this stage the dye is reduced and decolorized. The time required for such decolorization is, therefore, approximately the time required for the exhaustion of the available oxygen. The dye is an indicator for what may be called the oxygen neutral point, the point at which the available oxygen becomes exhausted and anaerobic conditions are established. Some studies [d] made at the sewage experiment station confirm the earlier conclusion of Spitta and Weldert, that the end point indicated by this dye is almost exactly the desired neutral point. The order in which different forms of oxygen are reduced appears to be: Dissolved oxygen, nitrates, nitrites, sulphates, and phosphates. Methylene blue was found to change color practically at the same time as the nitrites in this series. It is readily conceivable that an indicator might possess such properties that it would be reduced before the nitrates or even before the total exhaustion of the free oxygen. Another indicator might change only after the reduction of the sulphates. The fact of this varying end point has been well shown in a recent paper by Clark and Adams.[e] Comparative incubation tests were made with 17 dyes as indicators, only 6 of which were reduced during the incubation. Arranged in the order of their reducibility these are: Indigo carmine (sulphonated indigo), methyl-

[a] Archiv. für Hyg., 1903, vol. 46, p. 113.

[b] Spitta and Weldert, Mitteilungen aus der Königlichen Prufungsanstalt für Wasserversorgung und Abwässerbeseitigung zu Berlin, vol. 6, 1906, p. 161.

[c] Loc. cit.

[d] Phelps, E. B., and Winslow, C-E. A., On the use of methylene blue in testing sewage effluents: Jour. Infectious Diseases, Suppl. No. 3, 1907, pp. 1-13.

[e] Clark, H. W., and Adams, G. O., Studies in incubation tests: Jour. Am. Chem. Soc., vol. 30, 1908, p. 1037.

ene green, and methylene blue; and then, order not stated, congo red, methyl orange, and tropæolin. The average time computed from 26 tests for the reduction of indigo carmine was 2 days; for methylene green the average time was 2.4 days; and for methylene blue, 3.9 days. As it is of course impossible to hasten or to retard the reactions that are taking place, these differences show differences in the end point recorded by the several indicators.

In the writer's experiments it was shown that the end point indicated by methylene blue is probably that point at which the free oxygen and the nitrates are practically exhausted and reduction of the sulphates is just beginning. This is understood to be the point at which anaerobic conditions are established. The work was not undertaken, however, for the purpose of determining the end point accurately, and it is possible that the end point of methylene blue is a little too far along and that either methylene green or indigotin indicates the desired point more closely. Just as it is essential in other branches of analysis to specify the indicator that shall be used in a given determination, in order to prevent confusion in comparative work, similarly it is important in this test to adopt a standard indicator as a basis of comparison. The results of all experiments thus far are in favor of methylene blue, and that dye is now widely and satisfactorily used in the laboratories of the country; consequently, its retention as a standard appears advisable, at least until further experimental evidence is available. The present series of comparative stability values is calculated on the assumption that methylene blue be used. A change in the final end point adopted would, of course, necessitate a remodeling of the computations.

THEORETICAL RELATION BETWEEN REDUCING TIME AND RELATIVE STABILITY.

The time required for complete exhaustion of the oxygen from an effluent—the reducing time—is obviously not a simple function of its relative stability; but there is a well-known theoretical relation between velocity of reaction and amount of reacting substance, from which it is possible to compute one from the other. It is a principle of physical chemistry that the velocity of a chemical reaction is a function of some power of the concentrations of the reacting substances. In the simplest cases the velocity varies directly as the concentration. The bacterial reactions that have been investigated also conform to this law,[a] and it has been, therefore, applied to

[a] Chick, H., An investigation of the laws of disinfection: Jour. Hyg., vol. 8, 1908, p. 92.
Lubenau, C., Zur Saürebildung der Diphtheriebazillen: Arch. f. Hyg., vol. 66, 1908, p. 305.
Famalener, W., and Madsen, T., Die Abschwächung der Antigen durch Erwärmung: Biochem. Zeitung, vol 11, 1908, p. 186.
Nawiasky, P., Über die Umsetzung von Aminosaüren durch *B. proteus vulgaris:* Arch. f. Hyg., vol. 66, 1908, p. 209.

the present study. The exact expression of the function need not be detailed, for it can easily be seen that this general law is approximately applicable; if one-half the work of oxidation is accomplished in one day, the availability of the organic matter as a food supply is reduced one-half, and the consequent bacterial activity on the organic matter is reduced accordingly; at the beginning of the second day food supply and bacterial activity are in the same relative proportions and the same relative amount of work is done again; that is, one-half of the remaining work of oxidation will be done during the second day. This law is expressed by the following equation:

$$\log. x = \log. a - k^t$$

in which a is the amount of oxygen required for equilibrium at the commencement of the action, and x is the amount similarly required at the end of the time t, while k is a constant known as the velocity constant. If a grams of oxygen are required for initial equilibrium, and if x grams are required after the sample has been incubated in a tight bottle for a period of time which may be termed t days, $(a-x)$ grams of oxygen have been abstracted from the liquid by the organic matter. If the available oxygen of the liquid has just become completely exhausted at the end of t days, the value $(a-x)$ represents the amount of available oxygen originally present in the sample. It is not even necessary to know the actual amounts of oxygen, because the ratio of available oxygen to the oxygen initially required for equilibrium gives a relative stability factor that obviates the expression of the actual amounts. The ratio is

$$\frac{a-x}{a}$$

The value of this expression in terms of t and k can be found by using the logarithmic equation given above:

$$\frac{a-x}{a} = 1 - k^t$$

The second term of this equation, therefore, is equal to the ratio between the total available oxygen and the oxygen required for equilibrium, the ratio being expressed in terms of a constant and the reducing time. This ratio is the relative stability.

If a and x could be determined by analysis it would be possible to determine the value of k by a few tests. It has already been shown, however, that there is no simple chemical method of determining the amount of oxygen which is consumed by the organic matter under natural conditions. A possible method involves actual measurement of the amount of oxygen absorbed by the liquid in a time sufficiently prolonged to insure virtual equilibrium. If, how-

ever, k is determined only approximately and if a series of values for $(1-k^t)$ is obtained for all values of t, the terms of this series bear practically a constant relation to each other, even if k is varied considerably. The number expressing the relative stability is, in any case, a true index of the character of the effluent, independently of the further requirement that it shall be the absolute ratio of the available oxygen to the required oxygen. If it is not this absolute ratio it stands in constant but unknown relation to it.

An indirect method has been devised for determining the value of k with a degree of accuracy which is ample for the present discussion. For this purpose the results of 2,649 separate stability tests have been analyzed. The nature of these samples and the manner of determining the reducing time t is described on pages 78 to 80. It is sufficient to state that the reducing time was from one to twenty days in most of the tests, while many of the samples showed a relative stability of more than 100 per cent. As the samples which required a reducing time between one and twenty days had relative stabilities ranging from zero to 100 per cent, it was assumed for the purpose of approximating the value of k that one-half had values less than 50 per cent and one-half values greater than 50 per cent. Such assumption, of course, is justifiable only with a large number of observations, but it is believed that it is sufficiently accurate in the present case. Inspection of the tabulated results showed that a stability of 50 per cent was attained, at a temperature of 20° C., in almost exactly three days, thus making

$$1-k^3=0.50;\ \text{or}\ k=0.794.$$

If this value of k is substituted in the equation before mentioned, the following values of the relative stability corresponding to the time t in days are obtained.

TABLE 1.—*Relation between reducing time and relative stability at 20° C.*

Reducing time in days. (t.)	Relative stability. ($1-0.794^t$.)	Reducing time in days. (t.)	Relative stability. ($1-0.794^t$.)
1	21	9	87
2	37	10	90
3	50	11	92
4	60	12	94
5	68	14	96
6	75	16	97
7	80	18	98
8	84	20	99

These values of relative stability are strict measures of the character of the effluent. An effluent which contains more than sufficient oxygen to establish stability should have a stability of 100; in other words, it would never reach the anaerobic stage. In practice it is necessary to set some time limit to the tests and give an average

stability value to all tests exceeding this limit. This value is sufficiently high to indicate the character of the effluent. On the other hand, crude sewage containing a little dissolved oxygen is completely reduced in one or two hours, or, if it contains no dissolved oxygen, decolorizes methylene blue at once; in numerical expression its relative stability is practically zero. These figures are comparative, because they may be added and divided to obtain periodical averages and the averages thus obtained are properly weighted. This is not so if the reducing times themselves are averaged. The figures are also an approximate measure of the ratio between the total available oxygen in the effluent and the amount of oxygen required for the production of stable equilibrium in the organic matter, and it is believed that the approximation is sufficiently close for ordinary purposes of interpretation.

DETERMINATION OF RELATIVE STABILITY.

INCUBATION PERIODS.

Relative stability as previously defined is a numerical measure of the relation between available oxygen and required oxygen and it is also a function of the reducing time. Some practical applications of the stability values in Table 1 remain to be outlined.

Incubation periods exceeding five days are inconvenient and probably unnecessary in practical work, but in experimental work where more detailed knowledge is desired, longer periods may be used to advantage. At the sewage experiment station, a fourteen-day period has been adopted. During the past two years tests have been made of more than 2,600 samples of trickling-filter effluents of such a quality that most of them were near the border line between satisfactory and unsatisfactory effluents. Most of them were on the safe side, but some of them were unsatisfactory for considerable periods. The results of this large number of tests, therefore, constitute an admirable basis for studying the advisability of using shorter periods of incubation. In the summary of the results in Table 2 the tests are divided first in ten groups corresponding to the different filters and the years during which the tests were made. Effluents A, B, C, and D are from trickling filters before sedimentation; E and F are the same effluents after two-hour sedimentation. The results in each group are subdivided in order to show the per cent of the number of samples that retained available oxygen at the end of stated periods. The results shown in this table have been platted and from the plats the number of samples which would have retained available oxygen after twenty days have been determined by exterpolation from a plat of the results for shorter periods of time.

TABLE 2.—*Summary of stability tests of trickling-filter effluents, showing time required to exhaust the available oxygen.*[a]

Effluent.	Period.	Number of samples tested.	Per cent of samples retaining oxygen after—									
			1 day.	2 days.	3 days.	4 days.	6 days.	8 days.	10 days.	12 days.	14 days.	20[b] days.
A	1906–7	388	91	83	75	67	58	54	48	45	42	35
B		388	93	87	81	76	67	62	58	56	53	45
C		388	97	91	86	83	78	74	72	70	70	69
F		388	97	93	91	88	84	81	77	74	73	71
A	1907–8	223	38	32	28	25	22	20	17	15	15	14
B		225	39	31	25	22	14	9	6	5	4	3
C		212	29	19	12	6	5	4	3	3	2	1
D		189	17	5	1	1	0	0	0	0	0	0
E		38	50	37	21	11	5	5	2	0	0	0
F		210	20	14	10	6	3	2	1	1	1	1

[a] Indicator, methylene blue; temperature of incubation, 20° C. [b] Values exterpolated.

If it is assumed that in practice an incubation period of four days at 20° C. will be employed, it is possible to show from the data in Table 2 what relative stability values should be assigned to samples that retain some available oxygen after four days. Such samples may be divided into two hypothetical groups, namely, those which would have lost their oxygen between four and twenty days and those which would have retained it more than twenty days. Obviously a relative stability of 100 may be assigned to the latter because the value at twenty days is 99. An average time of ten days may be selected for the period between four and twenty days, thus making proper allowance for the decreasing number of samples, which reduce each day, and a relative stability of 90 may be assigned to that group. Between 43 and 63 per cent of the samples which passed the four-day period were reduced before twenty days. This per cent varied with the quality of the effluent, but it may be taken as 50 per cent without introducing an error of more than 5 per cent in the final result in any group. For practical purposes it may be assumed that one-half of all tests passing a four-day period of incubation will be reduced before twenty days, or in an average time of ten days, and that one-half will exceed twenty days. This gives 95 for an average relative stability value of the whole number of samples. If a four-day period of incubation at 20° C. is adopted, each sample reduced on the first, second, third, or fourth day may be recorded as having a relative stability of 20, 37, 50, and 60, respectively, and all samples retaining available oxygen after four days may be given a relative stability of 95. An individual result obtained in this manner will have but little accuracy, and when only a few tests are made, an incubation period of at least 10 days should be employed. On the other hand, when daily tests are made, the method outlined will give for monthly periods average results that are very close to the truth. Relative stability values calculated from the data in

Table 2 for the entire twenty-day period of incubation are compared in Table 3 with similar values obtained by the shorter, four-day, method. The agreement is satisfactory. If smaller numbers of tests are considered, the distribution naturally will not be so regular and greater errors will be introduced in the results calculated. In order to determine the accuracy of the proposed method, the first 776 samples of Table 2 have been subdivided into twelve quarterly groups, containing from 36 to 78 samples in each group, and the relative stability values have been calculated for these smaller groups, as shown in Table 4.

TABLE 3.—*Comparison of relative stability results obtained from the twenty-day incubation period shown in Table 2 with those calculated from a four-day period.*

Effluent.	Period.	Relative stability.	
		20-day period.	4-day period.
A	1906–7	76	77
B		81	82
E		88	86
F		86	84
A	1907–8	43	43
B		39	41
C		31	31
D		25	25
E		38	39
F		28	28

TABLE 4.—*Comparison of relative stability results obtained from smaller numbers of samples by the use of four, six, and twenty day incubation periods.*

Effluent.	Quarter.	Number of samples averaged.	Relative stability based on a—		
			4-day period.	6-day period.	20-day period.
A	1906.				
	First	37	59	59	58
	Second	73	57	53	52
	Third	59	64	61	60
	Fourth	77	89	88	88
	1907.				
	First	74	92	92	92
	Second	68	91	91	92
B	1906.				
	First	36	62	61	59
	Second	71	75	69	69
	Third	59	81	79	82
	Fourth	78	86	84	90
	1907.				
	First	75	91	90	95
	Second	69	91	90	93

The maximum error with the smaller groups is about 10 per cent, and this error can be materially reduced by basing the calculation on a somewhat longer incubation period. The second column in Table 4 shows the relative stability values calculated from a six-day

period, and the maximum error in this computation is less than 5 per cent. If the greater number of the samples of a well-purified effluent retain oxygen after four days, the results with any short method of calculation will be low. Since a value of over 95 can not be obtained with this method, it is obviously impossible to provide a four or six day method which will give accurate results. If more accurate information is necessary, longer periods of incubation—perhaps as long as ten days—are advisable. It matters little, however, whether the relative stability is 95 or 99, as far as practical results are concerned, because either value represents a high degree of purification.

EFFECT OF TEMPERATURE ON THE REDUCING TIME.

It has been assumed in the foregoing discussion that the temperature of incubation is 20° C., and there are certain reasons why this temperature is better than higher ones. It probably represents more nearly than any other the average temperature of streams, and results depending on bacterial activity should be obtained near the normal temperature to which the bacteria are exposed in nature. Incubations at 37° C., for example, probably cause the development of a class of bacteria quite different from those normally at work. The most serious objection to higher temperatures, however, is the fact that certain effluents, particularly those from the rapid filters which are in such common use, contain a large amount of dissolved oxygen, frequently 8 or 10 parts per million, and this represents the greater part of the available oxygen. At 20° C. 9 parts per million of oxygen is the saturation point. The saturation point at 37° C. has not been determined, but it is not over 7 parts per million, so that there is a tendency for some of the dissolved oxygen to escape at high temperatures. Tight stoppers will not prevent the escape of this released gas unless great care is taken with them, and mercury seals are hardly adapted to routine work. It is therefore practically impossible properly to maintain the necessary saturation conditions at a temperature higher than 20° C. A variation of temperature with season would have certain advantages, but such adjustment is rather impracticable. Since results are frequently obtained at 37° C., the relation of such results to those obtained at 20° C. has been investigated and has already been reported.[a] Variable relations were found, as was expected, but the average results may be used with some degree of accuracy. It was found that the time of reduction at 37° C. was from 37 per cent to 72 per cent of that required at 20° C., and the mean of 20 determinations was exactly 50 per cent. Carefully fitted glass stoppers were used in the bottles, and ordinary precaution was taken to prevent loss of

[a] Phelps, E. B., and Winslow, C. E.-A., loc. cit.

oxygen. If haste is necessary, a temperature of 37° C. will give results in about one-half the time required at 20° C. But the use of a temperature of 20° is strongly recommended whenever it is possible to employ it.

SUMMARY OF METHOD.

Samples should be collected in glass-stoppered bottles of 150 or 200 cubic centimeters capacity. No special precautions are necessary in collecting samples of ordinarily good effluents that are fairly high in dissolved oxygen. If the dissolved oxygen is low, precautions similar to those used in collecting dissolved oxygen samples should be observed. A one-tenth per cent solution of methylene blue, preferably Merck's medicinal quality, is used as indicator. One cubic centimeter of this solution is added to each of the samples, which are then incubated, preferably at 20° C., for four days, and observations are made at least once a day. The samples in which the methylene blue becomes decolorized are recorded as having a relative stability corresponding to the time required for reduction. Those that are blue at the end of four days are given a relative stability value of 95.

Table 5 gives the relation between time for reduction and the relative stability. Though the figures up to four days are the only ones required, the entire series up to twenty days is given for comparison. Relative figures for incubation at 37° C. also are given, but the use of that column is not recommended, except when it is absolutely necessary to use the higher temperature, or when it is desired to convert results to a standard basis of 20° C.

TABLE 5.—*Relation between relative stability and reducing time at 20° and at 37° C.*

Relative stability numbers.[a]			Relative stabilty numbers.[a]		
t_{20}.	t_{37}.	s.	t_{20}.	t_{37}.	s.
0.5	.....	11	8.0	4.0	84
1.0	0.5	21	9.0	4.5	87
1.5	.....	30	10.0	5.0	90
2.0	1.0	37	11.0	5.5	92
2.5	.....	44	12.0	6.0	94
3.0	1.5	50	13.0	6.5	95
4.0	2.0	60	14.0	7.0	96
5.0	2.5	68	16.0	8.0	97
6.0	3.0	75	18.0	9.0	98
7.0	3.5	80	20	10	99

[a] s=Relative stability or ratio of available oxygen to oxygen required for equilibrium. Expressed in per cent.
t_{20}=Time in days to decolorize methylene blue at 20° C.
t_{37}=Time to decolorize at 37° C.
Theoretical relation—
$s=100\ (1-0.794\ t^{20})$
$=100\ (1-0.630\ t^{37})$

INTERPRETATION OF RESULTS.

The arbitrary tests for putrescibility now employed require no interpretation. An effluent is either putrescible or nonputrescible, according to whether it is on one side or the other of a certain line of demarcation. The fact that the dividing lines, for there are many of them, are perfectly arbitrary and have no real significance seems to have been overlooked. Fixed arbitrary standards in sewage analysis are undesirable in that they relieve the analyst of the important and difficult duty of interpreting his own results in the light of his own peculiar environment. Some general observations and rules may be stated for aid in interpretation, but it should always be borne in mind that such interpretations are dependent as much on outside conditions as on the analyses themselves. The mere statement, therefore, that 75 per cent of the samples of a tested effluent were nonputrescible has no bearing whatever on the broader phases of interpretation. These facts are well known and accepted in ordinary analytical features. The aim of the present investigation has been to place the important determination of stability on the same basis. Under this proposed method of determining relative stability an interpretation of the information in hand is rendered possible. A relative stability of 75 per cent means that the effluent in question contains a supply of available oxygen equal to 75 per cent of the amount of oxygen which the effluent will eventually require before it will have become perfectly stable. The amount of this available oxygen is estimated fairly well by the chemical determination of dissolved oxygen and nitrates. The nitrites are usually so low that they are negligible, and it is unnecessary to decide whether or not the nitrates represent available oxygen, because they have been included in the test and must be considered in the interpretation. Undoubtedly the nitrates will not be used in the stream until the dissolved oxygen of the water has been reduced to a low point. Nevertheless, the fact remains that the available oxygen in the effluent, including the nitrates, is 75 per cent of that required for equilibrium, and that the remainder must come from the water of the stream, which must also supply enough additional oxygen to replace that which may be abstracted from the nitrates of the effluent, if aerobic conditions are to be maintained. Analyses of water from the stream and estimates of the relative volumes of the stream and the effluent complete the data necessary for a full interpretation.

In general, effluents having a relative stability greater than 90 per cent may be discharged into any stream without danger of their consuming any of the oxygen of the water, because effluents of such high stability will retain oxygen indefinitely on exposure to the air.

INDEX.

A.

Page.

Acids, use of, for disinfection 16–17
Alkalinity, effect of, on copper sulphate process 31
Amines process, description of 32–33

B.

Bacteria, fate of, in purification 8–12
purification by 7
Bacillus coli, persistency of 10, 12, 22–23, 36, 62–63, 72
tests for, records of 37
Bacillus pyocyaneus, persistency of 12
Bacillus sporagenes, persistency of 10
Bacillus typhus, persistency of 9, 62–63
Bacteria, sedimentation of 45–46
Bacteriological methods, description of 35–36
Baltimore, Md., experiments at 12, 14, 56–60
Baltimore sewerage commission, cooperation of 35, 56
Bengal, India, experiments at 24–25
Berlin, experiments at 19, 21–24
Birge, E. G., work of 35
Bleaching powder. *See* Chloride of lime.
Boston, investigations at 37–51
investigations at, character of 37–38
Brewster, N. Y., experiments at 27

C.

Calmette, A., experiments of 11
Carpenter, W. T., work of 35
Chemical disinfection, cost of 14
nature of 70–71
Chesapeake Bay, pollution of 13–14
Chloride of lime, amount needed of 38–39, 40, 43, 46, 48–51, 59, 63–65
amount needed of, relation of temperature to 43
contact period needed for 38–39, 45–46, 48–51, 64–65
disinfection by, cost of 65–70, 71–72
effect of, on colon and typhoid bacilli 62–63
evenness of, results with 43–45, 58–59
experiments with 38–51
penetration of solid particles by 22–23
price of 65–66
use of, as disinfectant 18–24, 71
Chlorine, electrolytic manufacture of 25–29
exhaustion of 62
germicidal action of 17, 60–62
use of, as disinfectant 17–29, 34, 71
Chlorine, available, definition of 18
Chlorine cells, description of 69
Chlorine compounds, germicidal action of 60–62
Chlorine gas, germicidal action of 60–61
production of 17–18

Page.

Chloros, nature of 19, 67
Clark, H. W., and Adams, G. O., on reducing time 79
Columbus, Ohio, experiments at 11, 29–31
Contact-filter effluents, bacteria in 11
effect of chloride of lime on 25
effect of copper sulphate on 30, 32
Contact period, length of, in chloride of lime process 38–39, 44–45
length of, in copper sulphate process 30
Copeland, W. R., and Johnson, G. A., experiments by 29–31
Copper, use of, for disinfection 29–32, 34
Copper sulphate, disinfection by, relation of temperature to 30, 43
Cowles, R. P., work of 35
Crawford, H. S., work of 34
Crude sewage. *See* Sewage.

D.

Daniels, F. E., work of 7, 34, 51
Delaware River, pollution of 14
Dibdin, W. J., experiments of 19
Digby, W. P., experiments of 67
Disease, effect of filter purification on 10
Disinfection, degree of 24
applications of 63–65
conclusions on 70–73
costs of 65–70
methods of 15–34
classification of 15
See also particular methods.
necessity for 12–15
See also Purification; Stability.
Drinking water, purification of, responsibility for 11–12, 70
Drown, T. M., on electrolytic process 26
Dunbar and Korn, experiments on 19
Dunbar and Zirn, experiments of 19

E.

Eau de Javelle, nature of 19
Electrolytic chlorine processes, cost of 66, 69–70, 71
description of 25–29, 67–69
Elsner and Proskauer, experiments of 19
Emerson, C. A., work of 35
Experimental investigations, account of 34–65
expression of 36–37

F.

Fermi, experiments of 27
Filter effluents, effect of chloride of lime on 25
effect of copper sulphate on 30–32
effect of sodium benzoate on 33
Filtration, effect of, on bacteria 9
Fuller, G. W., on oyster crop 13

G.

Page.
Gelatine, penetration of, by chloride of lime.. 22–23
Germany, chemical disinfection in..... 14

H.

Hamburg, experiments at..... 19–21
Heat, use of, for disinfection..... 15–16, 33
Hermite process, description of..... 27–28
Hospital sewage, experiments on..... 20
Houston, A. C., experiments of..... 9–10, 12
Hypochlorites, use of, in disinfection..... 18–25

I.

Ivanoff, investigations of..... 16

J.

Jackson, D. D., bile broth test of..... 11, 35
Johnson, G. A., experiments of..... 11
Johnson, G. A., and Copeland, W. R., experiments by..... 29–31

K.

Kellerman, K. F., and Moore, G. T., experiments of..... 29
Kellerman, K. F., Pratt, R. W., and Kimberly, A. E., experiments by.. 25, 31–32
Kitasato, investigations of..... 16
Klein, E. E., experiments of..... 15–16, 33
Korn and Dunbar, experiments of..... 19
Kranepuhl and Kurpjuweit, experiments of.. 21–22

L.

Labarraque's solution, nature of..... 19
Lillis, M. H., work of..... 35
Lime, use of, for disinfection..... 16

M.

MacConkey, Alfred, experiments of..... 9
McDonald Electrolytic Cell Co., aid of..... 35
McLintock, experiments of..... 27
McRae, H. C., work of..... 35
Marion, Ohio, experiments at..... 25
Massachusetts Institute of Technology, cooperation of..... 34
Moore, G. T., and Kellerman, K. F., experiments of..... 29

N.

New Jersey State Sewerage Commission, cooperation of..... 34

O.

Ohio, experiments in..... 25
Organic matter, effect of, on copper sulphate process..... 31
Oxychloride process, description of..... 28–29
Oxygen, available, definition of..... 77
Oxygen, required, definition of..... 77
Ozone, use of, as disinfectant..... 17

P.

Pathogens, fate of, in purification..... 8–10
Permanganate of potash, use of, for disinfection..... 32
Phelps, E. B., work of..... 7
Pickard, experiments of..... 9
Plainfield, N. J., experiments at..... 11–12

Page.
Potassium chlorate, germicidal action of..... 60–61
Potassium hypochlorite, germicidal action of.. 60–61
Potassium perchlorate, germicidal action of.. 60–61
Pratt, R. W., Kimberly, A. E., and Kellerman, K. F., experiments by.. 25, 31–32
Pritzkow, A., and Thumm, K., experiments of..... 11
Proskauer and Elsner, experiments of..... 19
Purification, agents of..... 7–8
  essentials of..... 12, 74
  significance of term..... 8
  speed of..... 7–8
    improvement in..... 7–8
  See also Stability; Disinfection.
Putrefaction, prevention of..... 8
Putrescibility, arbitrary standards of..... 88
  control of..... 74
  tests of..... 75–76, 88

R.

Red Bank, N. J., experiments at..... 51–56
  sewage-disposal works at..... 52
    plate showing..... 52
Reducing time, definition of..... 77
  estimation of..... 78–80, 83–86
  stability and, relation of..... 80–83
  temperature and, relation of..... 86–87
Relative stability. *See* Stability, relative.
Rideal, Samuel, investigations of..... 9, 16, 28

S.

Sand-filter effluent, bacteria in..... 11
  effect of chloride of lime on..... 25
  effect of copper sulphate on..... 30–32
Sand filtration, effect of..... 70
Schumacher, experiments of..... 19–20
Schwarz, investigations of..... 20–21
Septic effluent, chemical composition of..... 54
  disinfection of, cost of..... 55–56
  effect of chloride of lime on.. 24–25, 51–56, 64, 72
  effect of contact filter on..... 11
  effect of oxychloride on..... 28–29
  effect of sand filtration on..... 11
  effect of trickling filter on..... 11
  treatment of, by chloride of lime..... 24–25
Septic tank, effect of..... 9
Sewage, crude, disinfection of..... 46–47
  disinfection of, cost of..... 55–56
  effect of chloride of lime on..... 19–22, 23, 26, 46–51, 64, 72
  effect of contact filter on..... 11
  effect of copper sulphate on..... 30–32
  effect of oxychloride on..... 28–29
  effect of sand filter on..... 11
  effect of trickling filter on..... 11
  experiments on, in Germany..... 23–24
  sedimentation of..... 47
  superabundance of, effect of, on streams.. 8
  treatment of, by chloride of lime..... 23–24
Shellfish beds, protection of..... 13–14, 70
Sodium benzoate, use of, for disinfection..... 33
Sodium hydroxide, germicidal action of..... 60–61
Sodium hypochlorite, germicidal action of... 60–61
Sodium permanganate, use of, in disinfection.. 19, 32
Soil bacteria, purification by..... 7
Sprinkling filter effluent, effect of copper sulphate on..... 30

Page.
Stability, definition of 77, 88
necessity for 74
relation of time and 77–78, 80–83
Stability, relative, definition of 77, 85–86
determination of 83–86
Streams, purification of 8, 13
Stutzer, investigations of 16

T.

Temperature, effect of, on disinfection 43
effect of, on reducing time 86–87
Thumm, K., and Pritzkow, A., experiments of 11
Tonnetta Creek, N. Y., experiments on 27
Trickling-filter effluents, bacteria in 11
chemical composition of 40
effect of chloride of lime on 38–46, 56–60, 63–65, 71–72
Page.
Trickling-filter effluents, effect of copper sulphate on 30–31
effect of sodium benzoate on 33

V.

Vibrio, persistency of 21

W.

Walbrook, Md., testing plant at 56–57
Webster process, description of 26–27
Weldon chlorine process, description of 17–18
Whipple, Leyland, work of 35
Whitman, E. B., work of 7, 35
Wollheim, H., process of 32
Woodhead, Sims, investigations of 9
Woolf process, description of 27
Worcester, Mass., acid in sewage of 17

Z.

Zirn and Dunbar, experiments of 19

O

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

WATER-SUPPLY PAPER 230

SURFACE WATER SUPPLY OF NEBRASKA

BY

J. C. STEVENS

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CONTENTS.

	Page.
Introduction	5
Acknowledgments	5
Units and definitions	7
Stream measurements	9
General methods	9
Stout's method	10
Methods of computation	15
Use of formulas	15
The Harlacher formula	16
Accuracy and reliability of stream-flow data	17
Relation of rainfall to run-off	22
Limitations of rainfall records	22
Run-off formulas	23
Determination of mean annual run-off	24
Spring floods on Platte River	25
Available data for determining run-off	27
Conclusions	33
Outline of hydrographic data	33
Evaporation and seepage near Kearney	34
Platte River drainage basin	34
Platte River proper	34
Description of basin	34
Platte River near Lexington	35
Platte River near Columbus	42
Platte River at South Bend	55
North Platte drainage basin	56
Description of basin	56
North Platte River at Mitchell	58
North Platte River at Gering	66
North Platte River at Camp Clarke	71
North Platte River at Bridgeport	77
North Platte River at North Platte	84
South Platte drainage basin	99
Description of basin	99
South Platte River at Julesburg, Colo	101
South Platte River at Big Spring	108
Loup River drainage basin	110
Description of basin	110
Loup River at Columbus	111
North Loup River near St. Paul	126
Middle Loup River at St. Paul	133
Elkhorn River drainage basin	140
Description of basin	140
Elkhorn River near Norfolk	140
Elkhorn River at Arlington	150
Miscellaneous measurements in the Platte basin	157
Precipitation in the Platte drainage basin	162

Page.
Kansas River drainage basin 175
Description of basin 175
Republican River at Benkelman 176
Republican River at Bostwick 183
Republican River at Superior 183
South Fork of Republican River near Benkelman 199
Frenchman River at Wauneta 205
Frenchman River at Palisade 207
Miscellaneous measurements in Kansas River basin 211
Precipitation in the Republican basin 214
Niobrara River drainage basin 220
Description of basin 220
Niobrara River near Valentine 222
Niobrara River at Niobrara 231
Lakes in Cherry and adjoining counties 231
Miscellaneous measurements in the Niobrara basin 233
Precipitation in the Niobrara basin 236
White River and Hat Creek drainage basins 239
Description of basins 239
White River near Crawford 239
Miscellaneous measurements in White River and Hat Creek basins 240
Index 243

ILLUSTRATIONS.

Page.
PLATE I. Flood scenes at Lincoln 26
II. Sandy bed of Platte River 36
III. Canyons of Niobrara River 220
IV. *A*, Reservoir and power plant on Minnechaduza Creek; *B*, Niobrara River and "Chalk Bluffs" 220
V. Falls of Snake River 222
VI. Dam site on Snake River 224
FIGURE 1. Map of Nebraska 6
2. Cross sections of Loup River at Columbus 11
3. Rating Curve for Loup River at Columbus 12
4. Correction curves for Loup River at Columbus 14
5. Relation of rainfall to run-off in Nebraska 26

SURFACE WATER SUPPLY OF NEBRASKA.

By J. C. Stevens.

INTRODUCTION.

The material in this paper was compiled in 1904 as a thesis for the degree of bachelor of science in civil engineering at the University of Nebraska. The original manuscript has been revised and brought down to January, 1907, in order to satisfy a demand from engineers, irrigators, and the general public for a reference work covering all discharge data collected in Nebraska, inasmuch as the results of surface-water investigations in the State are widely scattered in numerous government and state publications, many of which are out of print and unavailable. Figure 1 is a map of the State, showing the principal streams and gaging stations.

ACKNOWLEDGMENTS.

The writer wishes to acknowledge special assistance and many valuable suggestions from O. V. P. Stout, professor of civil engineering, University of Nebraska, by whom or under whose immediate direction the major part of the data was obtained.

Acknowledgments are due to Adna Dobson, state engineer, secretary of the State board of irrigation, and his assistants in office, who have cheerfully furnished all information at their disposal and rendered much valuable assistance; to G. A. Loveland, section director of the United States Weather Bureau, for the liberal use of his office records; to the Burlington and Missouri River, the Union Pacific, and the Chicago and Northwestern railroads, whose cooperation has aided very materially in obtaining the data herein contained; and to Robert H. Willis, of Bridgeport, and H. O. Smith, of Lexington, for many measurements at regular and miscellaneous stations.

Thanks are also due to the many persons employed locally as gage-height observers for their interest and cooperation. Among these may be mentioned H. E. Dress, of North Platte, who has faithfully reported daily gage heights for the past twelve years; John Borman, of Valentine; E. J. Duryee, of Lexington; Burr Taft, of Norfolk; Mike Hamming, of Arlington; Porter Hannawald, of Bridgeport; and David Mowery, of Columbus.

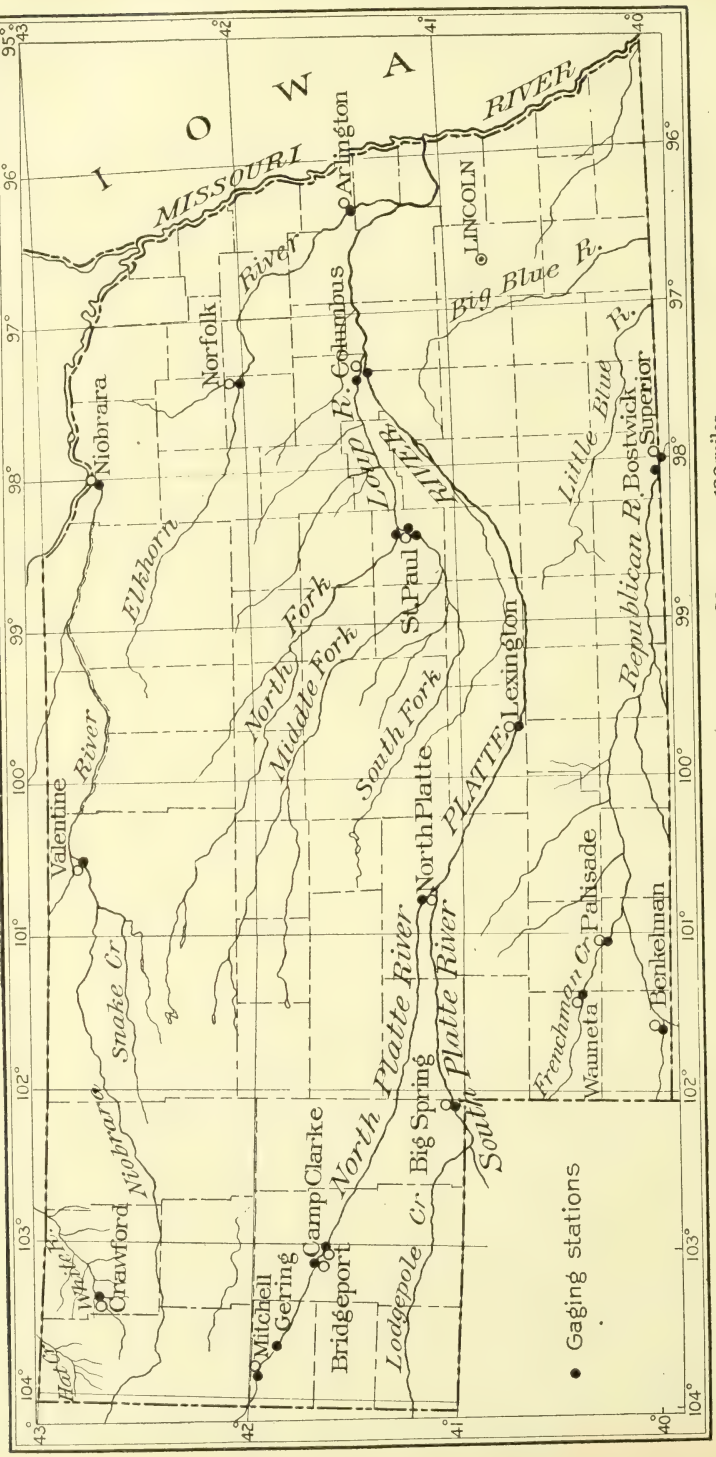


FIGURE 1.—Map of Nebraska, showing principal streams and gaging stations.

UNITS AND DEFINITIONS.

The volume of water flowing in a stream is expressed in various terms, each of which has become associated with a certain class of work. These terms may be divided into two groups—(1) those expressing a rate of flow, properly called the discharge, which may be expressed in second-feet, gallons per minute, or miner's inches; and (2) those expressing actual quantity, properly termed the run-off, which may be expressed in acre-feet or depth in inches.

"Second-foot" is an abbreviation for cubic foot per second, and is the quantity of water flowing in a stream 1 foot wide, 1 foot deep, at a rate of 1 foot per second. It is generally used as a fundamental unit from which others are computed.

"Gallons per minute" is generally used in connection with pumping and city water supply.

The "miner's inch" is the rate of discharge of water that passes through an orifice 1 inch square under a head which varies locally. It has been commonly used by miners and irrigators throughout the West, and is defined by statute in each State in which it is used. In most States, including Nebraska, the California miner's inch is used, which is the fiftieth part of a second-foot.

"Discharge per square mile" is applied to the average number of cubic feet of water flowing per second from each square mile of area drained, on the assumption that the run-off is distributed uniformly, both as regards time and area.

"Run-off in inches" is the depth to which the drainage area would be covered if all the water flowing from it in a given period were conserved and uniformly distributed on the surface. It is used for comparison with rainfall, which is expressed in depth in inches.

"Acre-foot" is equivalent to 43,560 cubic feet, and is the quantity required to cover an acre to the depth of 1 foot. It is commonly used in connection with storage for irrigation work. There is a convenient relation between the second-foot and the acre-foot. One second-foot flowing for twenty-four hours will deliver 86,400 cubic feet or approximately 2 acre-feet.

The following is a list of convenient equivalents:

1 second-foot equals 50 California miner's inches.

1 second-foot equals 38.4 Colorado miner's inches.

1 second-foot equals 40 Arizona miner's inches.

1 second-foot equals 7.48 United States gallons per second; equals 448.8 gallons per minute; equals 646,272 gallons for one day.

1 second-foot equals 6.23 British imperial gallons per second.

1 second-foot for one year covers 1 square mile 1.131 feet deep, or 13.572 inches deep.

1 second-foot for one year equals 0.000214 cubic mile; equals 31,536,000 cubic feet.

1 second-foot equals about 1 acre-inch per hour.

1 second-foot falling 10 feet equals 1.136 horsepower.

100 California miner's inches equal 15 United States gallons per second.

100 California miner's inches equal 77 Colorado miner's inches.
100 California miner's inches for one day equal 4 acre-feet.
100 Colorado miner's inches equal 2.60 second-feet.
100 Colorado miner's inches equal 19.5 United States gallons per second.
100 Colorado miner's inches equal 130 California miner's inches.
100 Colorado miner's inches for one day equal 5.2 acre-feet.
100 United States gallons per minute equal 0.223 second-foot.
100 United States gallons per minute for one day equal 0.44 acre-foot.
1,000,000 United States gallons per day equal 1.55 second-feet.
1,000,000 United States gallons equal 3.07 acre-feet.
1,000,000 cubic feet equal 22.95 acre-feet.
1 acre-foot equals 325,850 gallons.
1 inch deep on 1 square mile equals 2,323,200 cubic feet.
1 inch deep on 1 square mile equals 0.0737 second-foot per year.
1 inch equals 2.54 centimeters.
1 foot equals 0.3048 meter.
1 yard equals 0.9144 meter.
1 mile equals 1.60935 kilometers.
1 mile equals 1,760 yards; equals 5,280 feet; equals 63,360 inches.
1 square yard equals 0.836 square meter.
1 acre equals 0.4047 hectare.
1 acre equals 43,560 square feet; equals 4,840 square yards.
1 acre equals 209 feet square, nearly.
1 square mile equals 259 hectares.
1 square mile equals 2.59 square kilometers.
1 cubic foot equals 0.0283 cubic meter.
1 cubic foot equals 7.48 gallons; equals 0.804 bushel.
1 cubic foot of water weighs 62.5 pounds.
1 cubic yard equals 0.7646 cubic meter.
1 cubic mile equals 147,198,000,000 cubic feet.
1 cubic mile equals 4,667 second-feet for one year.
1 gallon equals 3.7854 liters.
1 gallon equals 8.36 pounds of water.
1 gallon equals 231 cubic inches (liquid measure).
1 pound equals 0.4536 kilogram.
1 avoirdupois pound equals 7,000 grains.
1 troy pound equals 5,760 grams.
1 meter equals 39.37 inches. Log. 1.5951654.
1 meter equals 3.280833 feet. Log. 0.5159842.
1 meter equals 1.093611 yards. Log. 0.0388629.
1 kilometer equals 3,281 feet; equals five-eighths mile, nearly.
1 square meter equals 10.764 square feet; equals 1.196 square yards.
1 hectare equals 2.471 acres.
1 cubic meter equals 35.314 cubic feet; equals 1.308 cubic yards.
1 liter equals 1.0567 quarts.
1 gram equals 15.43 grains.
1 kilogram equals 2.2046 pounds.
1 tonneau equals 2,204.6 pounds.
1 foot per second equals 1.097 kilometers per hour.
1 foot per second equals 0.68 mile per hour.
1 cubic meter per minute equals 0.5886 second-foot.
1 atmosphere equals 15 pounds per square inch; equals 1 ton per square foot; equals 1 kilogram per square centimeter.
Acceleration of gravity equals 32.16 feet per second every second.

1 horsepower equals 550 foot-pounds per second.
1 horsepower equals 76 kilogram-meters per second.
1 horsepower equals 746 watts.
1 horsepower equals 1 second-foot falling 8.8 feet.
1⅓ horsepower equals about 1 kilowatt.

To calculate water power quickly: $\frac{\text{Second-feet}}{11}$ = net horsepower per foot of fall on water wheel realizing 80 per cent of theoretical power.

STREAM MEASUREMENTS.

GENERAL METHODS.[a]

Discharge measurements are usually made with a current meter from a suitable bridge or cable, or, if the stream is shallow, by wading. The rate of discharge in cubic feet per second is the product of the area of the cross section of the stream in square feet and the mean velocity in feet per second. The mean velocity can not be obtained by direct measurement. It is usual, therefore, to divide the stream into a number of sections, and the velocity measured in each section is assumed to be the mean velocity for that section. The total discharge is the sum of the discharges in the several sections. Evidently the smaller the sections the more nearly the results so obtained approach the actual discharge.

In obtaining records of the daily discharge of streams the usual method employed is, briefly, as follows:

A gage rod, graduated to feet and tenths, is installed at a suitable point on the stream in such a position that the elevation of the surface of the water above some arbitrary datum plane can be read and reported each day by a local observer. The engineer in charge makes frequent visits to the station for the purpose of obtaining measurements of the flow by a current meter and noting the gage height. At the close of the season these measured discharges are plotted on cross-section paper as abscissæ, and the gage heights as ordinates. Through these points it is usually possible to draw a parabolic curve, termed the "rating curve" for that station, from which the discharge corresponding to any gage height may be obtained. In order to facilitate the application of such a rating curve, a rating table is prepared, giving the discharge for all gage heights throughout the range of the river's stage at intervals of tenths of a foot or less.

If the bed of the stream is composed of permanent material not greatly affected by the scouring effect of floods, the rating table may be expected to remain fairly constant from year to year, and the discharge measurements to conform very closely to a single rating curve. If, on the other hand, the bed of the stream is composed of

[a] For a more complete discussion of the methods employed by the United States Geological Survey in making stream measurements, see Water-Supply Paper 94 (Manual of hydrography) or the introduction to Water-Supply Paper 201.

loose shifting sands or silt, continual changes in the cross section of the stream result from the natural flow of the water, and large and sudden changes may be caused by floods. In such streams gage height and discharge may exhibit little or no conformity of relation, and therefore no single rating curve can be prepared that will correctly express this relation for any considerable period of time. Moreover, in any stream it is not sufficient, for reliable results, that the measuring section be located at a point where the bed is permanent, for even at such a point, if the stream bed immediately above and below this point is unstable, the slope of the water surface, and hence the velocity, of the stream will be greatly affected. In all such streams a single curve is applicable only for a limited period of time.

Almost without exception the streams of Nebraska are characterized by beds and banks of loose, shifting sand. Experience has shown that the only way in which reliable records of daily flow can be obtained for such streams is by the construction of measuring weirs or by making daily current-meter measurements. The excessive cost of either method prohibits its use, and it has therefore been possible to obtain only approximate results.

STOUT'S METHOD.

Even approximate results, however, have been made possible only through a method now known among hydrographers as "Stout's method," devised by O. V. P. Stout, professor of civil engineering in the University of Nebraska, and first described by him in the Nineteenth Annual Report of the United States Geological Survey, part 4, pages 323 et seq.

Briefly, this method merely minimizes the amount of labor otherwise involved in the preparation of a number of rating tables, each applicable for a limited period of time. It consists essentially in using a permanent rating table for each station and correcting the observed gage heights to what they presumably would have been were the bed and banks of permanent material. First, it is assumed that the changes occur at a fairly uniform rate between times of successive measurements. This assumption necessitates measurements at critical times when the rate of change is not uniform. As an example of the effect of a shifting bed on the relation between gage heights and discharge, two gagings made in 1903 on Loup River at Columbus may be given: March 20, gage height 5.10 feet, discharge 6,074 second-feet; May 7, gage height 5.10 feet, discharge 3,409 second-feet. In forty-eight days the bed of the stream so changed that for the same gage heights the discharge was only about half as much as at the earlier measurement.

Suppose that the bed of the stream was not subject to fluctuations, and there was available a rating table prepared on this basis, giving

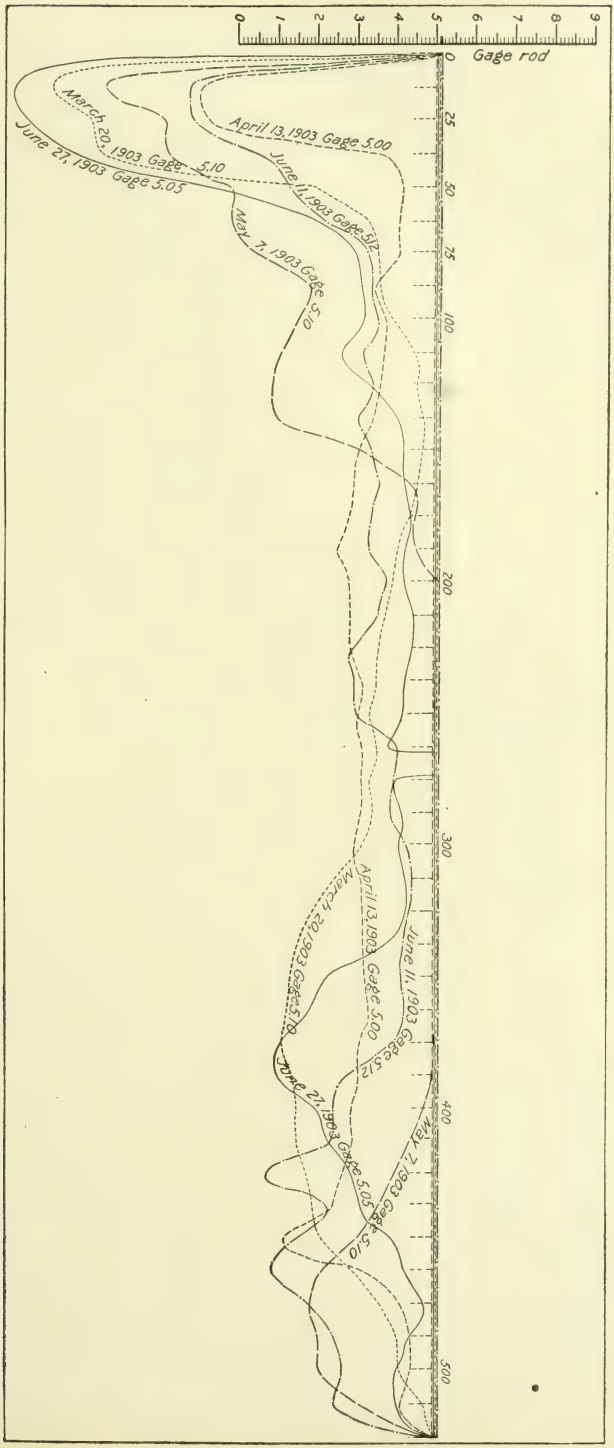


FIGURE 2.—Cross sections of Loup River at Columbus.

the discharge of the stream for all gage heights. Taking the discharge found on March 20 above and entering such a rating table, we find the gage height required to give this discharge. The difference between the observed gage height and that taken from the rating table is the correction to be applied to the gage heights for that day. Graphically the correction is the distance between any plotted point of measurement and the curve, measured parallel to the gage-height axis, plus if the point falls below the curve and minus if above. In a similar manner the correction for the measurement of May 7 is obtained. No flood occurred between these dates (see gage heights, pp. 122–123), and there is no reason to believe that changes in the

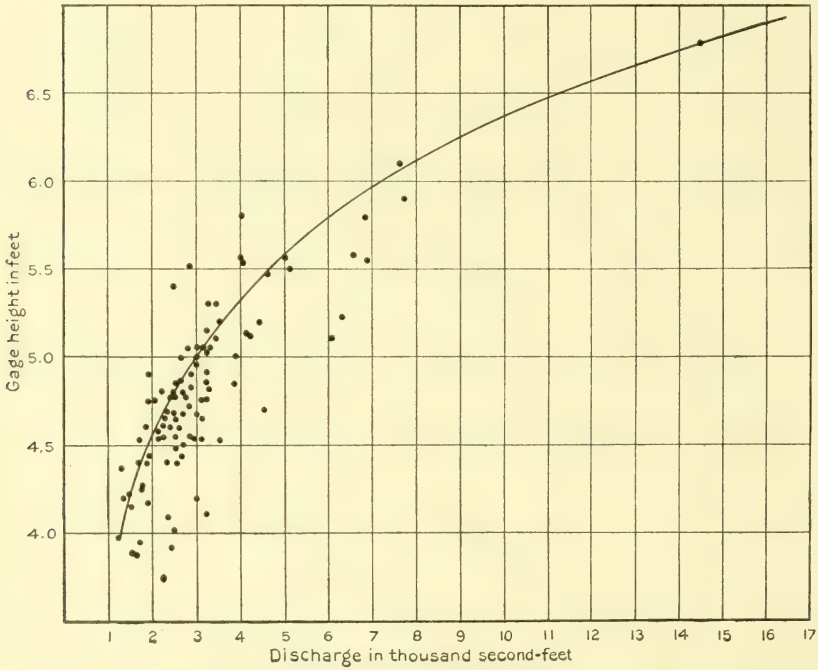


FIGURE 3.—Rating curve for Loup River at Columbus.

stream bed occurred at other than a fairly uniform rate. The corrections to be applied for intermediate dates are obtained by direct interpolation or more accurately read from a correction curve.

It is evident from a study of this method that practically the same results are obtained by it as by the use of a series of rating tables, each applicable for a short period of time. Of course the ideal rating table does not exist, and the one used is that one which conforms the best to all measurements made at the gaging station.

Owing to the rapid velocities and the large quantities of water that are at times discharged, perhaps no stream shows such utter lawlessness as Loup River. Figure 2 illustrates by means of cross sections,

obtained from five successive discharge measurements, the changes that may occur in this stream. As indicated by these sections there is very little fluctuation in the water surface, but within the period of a few weeks the bed of the stream exhibits radical changes which, however, are not abnormal, as the river remained at an ordinary stage throughout the period. In figure 3 the discharge measurements made at the Columbus station on Loup River are plotted together with the rating curve from which corrections to gage heights are obtained. The position of the points seem to be limited only by the margin lines of the diagram. The curve drawn was constructed early in the history of the station, and as practically the same final results would be obtained by the use of any parallel curve it has not been modified. The following table gives the discharge from this curve at intervals of tenths of feet of gage height:

Rating table for the indirect application of gage heights for Loup River at Columbus.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
4.0	1,220	5.0	3,000	6.0	7,050
.1	1,300	.1	3,260	.1	7,800
.2	1,400	.2	3,550	.2	8,750
.3	1,510	.3	3,890	.3	9,750
.4	1,660	.4	4.300	.4	9,750
.5	1,820	.5	4,740	.5	10,750
.6	2,040	.6	5,180	.6	11,750
.7	2,260	.7	5,620	.7	13,750
.8	2,500	.8	6,060	.8	14,750
.9	2,740	.9	6,500	.9	15,750

To illustrate more clearly the method of applying corrections to the gage heights, the records for the year 1903 are given as an example. The following table gives the results of measurements made at this station during that season, showing the gage height, the discharge, the corrections to be applied as determined from the above rating table, and the gage heights as corrected:

Discharge measurements made on Loup River at Columbus, 1903.

Day.	Hydrographer.	Gage height (feet).			Discharge (second-feet).
		Observed.	Correction.	Corrected.	
Mar. 20	J. C. Stevens	5.10	+0.70	5.80	6,074
Apr. 3	do	5.00	+ .30	5.30	3,905
May 7	do	5.10	+ .05	5.15	3,409
June 11	do	5.12	0	5.12	3,432
June 27	do	5.05	− .10	4.95	2,799
July 10	do	4.67	+ .30	4.97	3,022
July 17	do	5.56	0	5.56	5,022
Aug. 1	do	6.78	0	6.78	14,580
Aug. 18	do	5.13	+ .20	5.33	4,177
Sept. 19	F. C. Murphy	4.49	+ .35	4.84	2,644
Sept. 29	J. C. Stevens	4.40	+ .35	4.75	2,328
Oct. 30	do	4.61	+ .25	4.86	2,607
Dec. 20	do	6.50	−1.80	4.70	2,280

If all the corrections so obtained are plotted as ordinates and time in days as abscissæ, a curve called the correction curve is obtained. The ordinate to the curve gives the correction for that day, positive or negative as the case may be, which should be applied to the gage height reported by the observer. The corresponding discharge is then taken from the rating table, the *corrected* gage height being used. To illustrate: The gaging of March 20, 1903, shows a discharge of 6,074 second-feet, with a gage height of 5.10 feet. Entering the rating table with this discharge, we find that a gage height of 5.80 feet would be required to give this discharge. The correction to be applied to the gage height on March 20, therefore, is +0.70. On April 3, with a gage height of 5.00 feet, the discharge was found

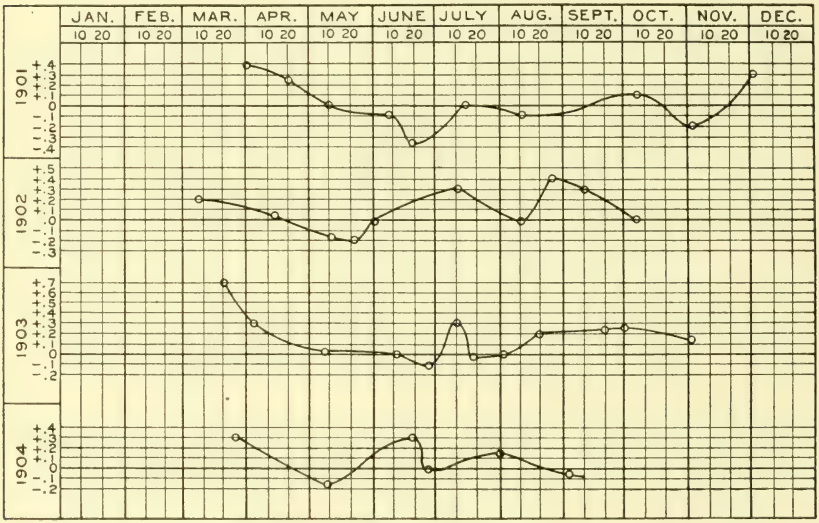


FIGURE 4.—Correction curves for Loup River at Columbus.

to be 3,505 second-feet, which would require a gage height in the rating table of 5.30 feet; and the correction to be applied to the gage height on April 3 would, therefore, be +0.30. Similarly on May 7 the correction is found to be +0.05. On June 11 the correction to gage height is found to be practically zero; on June 27 it is −0.10. On July 4 and 5 an excessive flood occurred, shortly after which, on July 10, the correction to gage height was found to be +0.30. On July 17 it had dropped to zero again, where it continued until the flood on August 15, after which positive corrections ranging from +0.20 to +0.35 are required to the end of the season. The correction curves for the years 1901 to 1904, inclusive, are shown in figure 4, a study of which will show that these curves determine to a greater or less extent the changes which take place in the bed of the stream.

Taking the curve for 1903, and imagining a mean condition of the bed of the stream, on each side of which these fluctuations may be assumed to occur, we readily see that a positive correction to the gage heights will indicate that the bed of the stream has been washed out below that of the mean bed; in other words, that the cross-sectional area of the stream at the gage has been enlarged so that a greater quantity of water can pass the gaging section without increasing the gage height, or that changes above or below have unduly increased the velocity. On the other hand, a negative correction to gage height indicates that the bed of the stream has filled in and the cross-sectional area is less than that which would otherwise be indicated for the same gage height, or that the velocities have been unduly retarded.

The slope of the correction curve also indicates the direction in which these changes are occurring. Thus if the curve slopes downward in the direction of time, it indicates that the bed of the stream at this point is being filled; and if it slopes upward in the direction of time it indicates a scouring effect. For example, it appears that from March 20 to June 27, 1903, the bed of the river was gradually filling up, and that from about May 7 to June 11 the bed of the river was practically stationary and very nearly conformed to the mean condition heretofore mentioned. About July 5 there was an excessive flood that had the effect, as indicated by the direction of the correction curve, of scouring out the channel, which, however, almost as quickly filled in as the flood receded, continuing nearly stationary till the end of the month, when another flood occurred that again scoured out the bed of the stream. Large floods in the middle and the latter part of August kept the bed scoured out throughout the month of September, but it filled in very gradually during October.

It is interesting to note the general resemblance which these curves bear to one another. On the breaking up of the ice in the spring the bed is usually washed out, but during the spring months it is gradually filled in. In July and August floods occur without regularity from year to year, and may or may not have their effect on the form of the correction curve.

METHODS OF COMPUTATION.

USE OF FORMULAS.

The field notes of a discharge measurement by current meter give (1) depth of water in the cross section, usually at regular intervals from an initial point; (2) the number of revolutions of the current meter in a given number of seconds observed at each point of depth measurement from which the velocity at these points can be determined.

A number of formulas are in use for computation of the discharge from field notes, no two of which will give exactly the same results; yet all give results well within the limit of accuracy of the measurement itself. It is therefore economy of time and energy to adopt the simplest formula. Consider the rate of discharge as the volume passed over in one second of time by all the particles of water in a plain cross section of the stream. The advancing face of such a volume will be a curved surface, usually concave, in both horizontal and vertical projection, to the planes of reference. The vertical sections of this surface are termed vertical velocity curves, and the horizontal sections horizontal velocity curves. In the field the attempt is made to determine the mean velocity in the vertical by methods described in detail in the introductions to Surface Water-Supply Papers for 1906 (Nos. 201–214).

The computation of discharge is therefore simplified to the operation of finding the cubic contents of the volume generated by moving each vertical in a plain cross section a distance downstream equal to the mean velocity in that vertical. Of such a volume all horizontal sections are bounded on the advancing face by the same curved line and all vertical sections are rectangles whose areas are the product of depth by velocity at that point. Any formula which will not lend itself to the determination of the cubical contents of such a volume can not legitimately be used as a discharge formula.

Let d_1, d_2, d_3, etc., be depths measured at regular intervals l from the initial point. Let v_1, v_2, v_3, etc., be corresponding velocities. The volume of discharge is made up of a series of prismoids each of length l bounded by the "end areas" d_1v_1, d_2v_2, d_3v_3, etc. The volume of each prismoid is given by the prismoidal rule—

$$q = \frac{l}{6}\left[d_1v_1 + 4\left(\frac{d_1+d_2}{2}\right)\left(\frac{v_1+v_2}{2}\right) + d_2v_2\right]$$

and the total discharge is the sum of the volumes of all such prismoids. This of course involves the assumption that velocities and depths vary uniformly between points of measurement, and in practice measurements should be made close enough together to conform to this assumption.

THE HARLACHER FORMULA.

The preceding formula is too cumbersome for practical application, and a substitute approximate formula, now generally known as the Harlacher method, has been used almost exclusively in Nebraska. It consists essentially in considering a prismoid of length $2l$ so that the mid-area is actually measured and not computed. The formula for a prismoid of length $2l$ becomes—

$$q = \frac{2l}{6}(d_1v_1 + 4d_2v_2 + d_3v_3)$$

By adding the volumes of successive prismoids the total discharge is expressed in general as follows: Where h is substituted for (dv) and n is an even number,

$$q=\frac{l}{3}[h_0+4(h_1+h_3+\ldots h_{n-1})+2(h_2+h_4+\ldots h_{n-2})+h_n]$$

It is evident that this is merely Simpson's "one-third rule" for the area of irregular figures, except that the areas are substituted for ordinates. In the original presentation of the method the discharge was considered as proportional to the area bounded by a curve the ordinates to which were the products of depth by velocity at all points.

The errors involved by the use of this formula are indeterminate except for specific cases. If the horizontal velocity curve is continually concave to the axis of reference the error is small; if, on the other hand, the direction of curvature is reversed several times, the error may be large and different results may be obtained from the same set of field notes, if different points are taken as the beginning of application of the formula.

As previously stated, however, the errors of computation are insignificant compared with those of observation.

ACCURACY AND RELIABILITY OF STREAM-FLOW DATA.

In the analysis of hydrographic data for any particular purpose a question often arises as to the accuracy and reliability of the records, that is, how nearly do the figures given for the estimated discharges conform to the actual volume of flow? The errors resulting from observations of depth and velocity in making discharge measurements, the permanency of the rating curve, the reliability of the local observer, the frequency of making observations of gage heights and discharge measurements, the nature of the stream as to permanency of bed and fluctuations of velocity, and the local conditions surrounding the gaging station must all be considered in answering this question.

The errors of discharge measurements have been made the subject of special study by various hydrographers. One of the most complete discussions of the subject is that published by the United States Geological Survey in Water-Supply Paper 95, entitled "Accuracy of stream measurements," by E. C. Murphy.

That too much dependence is often placed on the results obtained is evident on consideration of the various errors that make up the total error of a discharge measurement. For example, a measurement made with a current meter is subject to errors in the meter rating, in measuring depth, and in counting the revolutions of the meter vane, all of which may be termed accidental errors. In addi-

tion there are the errors resulting from the fluctuations in velocity from the change of stage during the time of measurement, from the effects of wind, and from the impracticability of determining with absolute accuracy the mean velocity in any vertical, all of which have a material and largely indeterminate effect on the discharge measurement.

No definite general figures can be given for such errors, as they are different in every case. It would be possible to determine the errors in the meter rating, in counting the revolutions of the meter vane, and in measuring the depth, but such determinations are of little value if the more important errors due to fluctuations of velocity and stage are omitted.

For example, if, instead of the prismoidal formula on page 16, we consider an elementary volume of discharge extending a distance $\frac{1}{2}l$ on each side of a point where depth and velocity are measured, the discharge through such a section will be $q = ldv$. Now, let r = error involved in measuring the depth; r_1 = error involved in measuring the corresponding velocity; e = error of discharge q in a single prism of length l. From the law of facility of errors for nonlinear functions the error of discharge in a single prism is expressed by—

$$e^2 = r^2\left(\frac{dq}{dd}\right)^2 + r_1^2\left(\frac{dq}{dv}\right)^2.$$

But $\frac{dq}{dd} = lv$ and $\frac{dq}{dv} = ld$. Substituting $e^2 = l^2(r^2v^2 + r_1^2d^2)$.

Now, if r and r_1 be expressed in percentages of d and v, respectively, the above equation reduces to $e^2 = l^2d^2v^2(r^2 + r_1^2)$, and since ldv is the discharge through the section the percentage of error of the discharge is $\frac{e}{q} = \sqrt{r^2 + r_1^2}$; that is to say, the percentage of error in the discharge of a section is the square root of the sum of the squares of the errors involved in measuring the depth and velocity expressed in percentage. Thus, if depth error is 3 per cent and velocity error 4 per cent, the resulting error in the discharge is 5 per cent. As a matter of fact, the errors of measuring depth and velocity are not properly expressed in percentages, but rather as absolute quantities. The error in velocity determinations rather than the error in depth determinations will in general govern the error of discharge.

In July, 1904, two series of measurements were made on Loup River, at Columbus and Niobrara River at Valentine, for the purpose of determining the accuracy resulting from gaging as ordinarily made at these stations.

At the Columbus station measurements were made from a cable and car which spans the river about 75 yards above the Union Pacific Railroad Bridge. The channel at the time of the measurements was

515 feet wide. The depths varied from 1 to 7 feet and the velocities from 1 to 5 feet per second. The bed of the stream is composed entirely of loose, shifting sand, which, considering the swiftness of the current, made it impracticable to measure depths with an error of less than about 0.3 foot in the swiftest water. Individual velocity determinations are probably accurate within 5 per cent.

The gagings were made in four sets of two each. In sets A, B, and C the two gagings were made simultaneously by two hydrographers operating from different ends of the car, so that each gaging is entirely independent of the other. Depths and velocities were measured at 12½-foot intervals, the initial point of each gaging in the set being different. In these three sets the 0.6 method of obtaining mean velocities in the vertical was used. In set D one gaging followed the other, and velocities were taken by the integration method. Set A was made July 29, and sets B, C, and D on the 31st; but the change in the river stage was so slight that the two days' work has been considered together.

It has been assumed that the differences in the discharges obtained were due mainly to two general causes: (1) Errors in fluctuation, including the slight changes in the stage and fluctuations of velocity; (2) accidental errors, which include errors in measurement and observation. An attempt has been made to eliminate in part the errors due to change of stage by referring the discharges to a mean gage height. For example, the mean of the several mean gage heights is 4.80; the mean gage height of the first set of gagings was 4.82. The difference is 0.02, which corresponds to an increased discharge of 28 second-feet over that which would have been obtained had the gaging been made with a gage height of 4.80, other conditions remaining the same. The large error of the first gaging—518 second-feet—may be accounted for in part by the fact that an insufficient weight was tied on the meter, thus allowing the depths to be recorded in excess of what they actually were, the meter being carried downstream by the swift current. This source of error was eliminated in the remaining measurements.

It appears from an examination of the table below that gagings at this point with an error of less than 15 to 20 per cent need not be expected, unless exceptional precautions are taken.

It must be borne in mind that "standard cross sections" can not be used on streams of this class. Cross-sectional areas must be determined at each time of gaging. The area, and hence the discharge of the first measurement, are undoubtedly in error, as explained above. Nevertheless the result is all the more valuable as indicating what might have happened had the hydrographer been content with this one measurement for fixing this portion of the rating curve for the season. Cross sections at this station are shown in figure 2 (p. 11).

Discharge measurements on Loup River at Columbus to determine degree of accuracy resulting from gagings as ordinarily made.

Set.	No.	Date, 1904.	No. of meter.	Method of obtaining velocities.	Time of gaging.		
					Beginning.	Ending.	Duration.
							Hrs. min.
A	1	July 29	342	0.6	11.00 a. m.	1.00 p. m.	2 0
	2	do	347	.6	do	do	2 0
B	3	July 31	342	.6	10.15 a. m.	12.00 m.	1 45
	4	do	347	.6	do	do	1 45
C	5	do	342	.6	12.40 p. m.	2.00 p. m.	1 20
	6	do	347	.6	do	do	1 20
D	7	do	342	Integration.	2.00 p. m.	3.05 p. m.	1 5
	8	do	342	do	3.05 p. m.	4.10 p. m.	1 5

Set.	No.	Gage height (feet).			Area of cross section (square feet).	Mean velocity (feet per second).	Discharge (Q) (second-feet).	Discharge corrected for change of stage (Q′) (second-feet).	Residual $(Q'_m - Q')^a$ (second-feet).	$\frac{Q'_m - Q'}{Q'_m}$ (per cent).
		Beginning.	Ending.	Mean.						
A	1	4.82	4.82	4.82	1,274	2.64	3,376	3,348	−518	−18.3
	2	4.82	4.82	4.82	1,130	2.57	2,896	2,868	− 38	− 1.3
B	3	4.77	4.77	4.77	1,036	2.63	2.723	2,763	+ 67	+ 2.4
	4	4.77	4.77	4.77	1,067	2.60	2,778	2,818	+ 12	+ 0.4
C	5	4.77	4.80	4.78	1,084	2.52	2,737	2,765	+ 65	+ 2.3
	6	4.77	4.80	4.78	1,018	2.78	2,826	2,854	− 24	− 0 8
D	7	4.80	4.80	4.80	1,020	2.44	2,492	2,492	+338	+12.0
	8	4.80	4.80	4.80	1,045	2.61	2,734	2,734	+ 96	+ 3.4

^{a} Q'_m=mean value of Q′=2830.

NOTE.—Warm, still day. Conditions favorable for good results. Gagings and computations by J. C. Stevens, assisted by O. H. Timmerman.

A similar series of measurements was made on Niobrara River at Valentine. The same general method of referring the discharge to the mean gage height was adopted in order to eliminate the effects of fluctuations of the water surface. The reading of the gage was checked before and after each gaging by measuring down to the water surface from a permanent point on the bridge. The gagings were made from a single-span steel bridge, the tubular piers of which did not obstruct the channel. The bed of the stream is made up of sand mixed with bowlders and cobblestones. The depths varied from 1 to 2 feet and the velocities from 1 to 5.5 feet per second. The depths have an error of about 0.2 foot, and individual measurements of velocity are probably accurate within 4 per cent. The width at the upstream side of the bridge was 115 feet and at the downstream side 123 feet. Observations were taken at intervals of 5 feet, a different initial point being used in each measurement.

A number of duplicate measurements have been made at this point from time to time, the results of which are also shown below.

The results appear to show a greater degree of accuracy than might be expected in view of the conditions. Yet it is believed that measurements at this point can be made with errors not exceeding 4 or 5 per cent.

Discharge measurements on Niobrara River at Valentine, July 11, 1904, to determine degree of accuracy resulting from gagings as ordinarily made.

No.	Method of obtaining velocities.	Side of bridge.	Time of gaging.			Gage height (feet).			Area of cross section (square feet).	Mean velocity (feet per second).	Discharge (Q) (second-feet).	Discharge corrected for change of stage (Q′) (second-feet).	Residual ($Q'_m - Q'$)[a] (second-feet).	$\frac{Q'_m - Q'}{Q'_m}$ (per cent).
			Beginning.	Ending.	Duration (minutes).	Beginning.	Ending.	Mean.						
1	0.6	Upstr.	8.25 a.m.	9.15 a.m.	50	1.43	1.45	1.44	197	3.86	761	783	−16	−2.1
2	.6	Downstr.	9.40 a.m.	11.15 a.m.	95	1.45	1.52	1.48	194	3.90	756	760	+ 7	+0.9
3	.6	Upstr.	3.10 p.m.	3.45 p.m.	35	1.54	1.52	1.53	197	4.07	801	782	+15	+2.0
4	.6	Downstr.	3.45 p.m.	4.15 p.m.	30	1.52	1.50	1.51	184	4.09	752	743	+24	+3.1
5	Integr.	....do....	4.15 p.m.	5.00 p.m.	45	1.50	1.44	1.47	189	4.02	760	769	− 2	−0.3

[a] Q'_m=mean value of Q'=767.

NOTE.—Warm, still day. Conditions favorable for good results. Gagings and computations by J. C Stevens. Meter No. 347.

Duplicate discharge measurements made on Niobrara River at Valentine.

Date.	Hydrographer.	Gage height.	Discharge.	$\frac{Q_1 - Q_2}{Q_1 + Q_2}$ (per cent).[a]
May 26, 1903	J. C. Stevens	1.55	873	±1.2
Do	....do	1.55	894	
Sept. 17, 1903	E. C. Murphy	1.38	709	± .4
Do	....do	1.38	715	
April 17, 1904	J. C. Stevens	1.57	683	±3.3
Do	....do	1.57	640	

[a] The mean of the two gagings was assumed to be the correct discharge and the per cent of error computed on this basis; that is, 1/2 $(Q_1 - Q_2)$ is the residual and $\frac{1/2\ (Q_1 - Q_2)\ 100}{1/2\ (Q_1 + Q_2)}$ is the percentage of error.

From the foregoing discussion it is evident that individual measurements are liable to an error of 5 to 20 per cent. The errors resulting from external sources, such as unreliability of the observer's reports; from the assumption that a single gage-height observation or the average of two observations is actually the mean for the day; from the error of using a mean gage height for finding mean daily discharges; and from the unknown and largely indeterminate effect of climatic conditions at the station from day to day can be only a matter of conjecture.

The true worth of a hydrographer lies not so much in being able to measure streams accurately and develop correct discharge curves, as in having a logical conception and a working knowledge of the actual worth of hydrographic data. This knowledge can not be obtained from books.

RELATION OF RAINFALL TO RUN-OFF.

LIMITATIONS OF RAINFALL RECORDS.

It is hardly necessary to say that in any region where a knowledge of the distribution and duration of the various rates of stream discharge is a requisite for its proper development, no method of obtaining that knowledge can compare in reliability with actual systematic stream measurements, extending over a period of several years. It will also be evident after a little investigation that records of rainfall are entirely inadequate for this purpose. It is, however, frequently necessary to make some estimate of the quantity of water yielded by a particular drainage basin on which no systematic records of stream flow have been kept. For this purpose it is almost useless to attempt the determination of the time distribution of the various rates of discharge, but efforts must be confined to discovering either the mean annual yield, the quantity supplied year by year, or that supplied during distinct climatological periods of the year.

A consideration of some of the natural conditions affecting the relation between the discharge of a stream and the precipitation on its watershed will substantiate this statement. As all flowing water must at some recent period have passed through the state of precipitation, it follows that there must be some definite relation between rainfall and run-off, and the fact that it can not be determined is merely proof that all the conditions influencing this relation are not taken into account. These conditions are best illustrated by concrete examples. Consider first the simplest possible case, that of an impervious roof of known area and known slope from which the water is conducted by eave troughs over a weir to a reservoir. Assume also a rain gage in place to determine the precipitation. The effect of evaporation being disregarded, the total quantity falling on the roof in any period of time will later appear in the reservoir and should be equivalent to the depth shown by the rain gage multiplied by the horizontal projection of the roof area. The determination of the rate of run-off is a different problem, for to find this it is necessary to know the rate of rainfall; then from observations of the rate of flow over the weir, the storage capacity of conduits to the weir, and the rate at which water was stored therein, it would be possible to determine the relation between the rate of rainfall and the rate of run-off for that particular roof, at that particular angle, with that particular system of conducting the water therefrom. The mean rate is of course the total quantity precipitated divided by the time, but that is merely expressing quantity in another unit. The maximum rate would be indeterminate without elaborate preparations.

If, instead of the smooth impervious roof, an area of sod, soil, sand, and gravel of unknown thickness is considered, the quanti-

tative determination could even in this case be made, but account would have to be taken of the previous saturated condition of the material and the evaporation, as the observations would have to be extended over a much longer period of time to attain any degree of accuracy. The maximum rate of run-off could be determined for only that particular condition of saturation existing previous to the rainfall.

When it is realized that the conditions in nature are far more complicated than can be illustrated by a simple case like those cited—that the precipitation occurs under all climatic conditions from torrential cloud-bursts of a few minutes' duration to gentle showers lasting for weeks, from driving blizzards on frozen ground to fleecy snows that melt into slush during the day and freeze at night; when it is considered that records of precipitation at best are only approximations, with rarely any attempt at rate determination, and that frequently stream-flow data are quite as inaccurate and incomplete, it is evident that little will be gained by a laborious analysis of rainfall records when a common-sense guess will frequently furnish just as reliable data.

George W. Rafter, in a report on the relation of rainfall to run-off,[a] says: "In computing the run-off of various streams, small discrepancies will continually appear; when such do not exceed 1 to 2 inches they are outside the limits of discussion." Now, 2 inches is four times the annual run-off from the drainage basin of Republican River, and practically all streams of the western plains are excluded from his discussion; yet many instances can be cited where engineers have applied to streams in the arid West the formulas developed for streams in the eastern, humid part of the United States, and with this flimsy foundation built works of considerable magnitude, only to find themselves outwitted by nature.

It is therefore high time that some actual facts and figures were given and the marked individuality of the streams of the plains in this regard forcibly pointed out. Negative information is often the most valuable, and of this there is no lack.

RUN-OFF FORMULAS.

It is evident that a determination of the rate of stream discharge from records of rainfall is practically out of the question, and that any quantitative analysis is only the roughest approximation; an examination of some of the formulas now in use purporting to express this relation will therefore be of interest.

J. T. Fanning proposes the formula $D = 200\ M^{5/6}$ where D is the discharge in second-feet and M the drainage area in square miles. This relation was determined by plotting the flood discharge of some American streams.

The Ryves formula is $D = CM^{2/3}$, and Dickens proposes $D = CM^{3/4}$.

[a] Water-Supply Paper U. S. Geol. Survey No. 80, 1903.

In these two formulas C is a sliding coefficient, depending on the natural characteristics of the drainage basin. For the Dickens formula C has the following values for flat countries: Where rainfall of 3.5 to 4 inches in twenty-four hours may occur, 200; for a maximum rainfall of 6 inches, 300. The Ryves coefficient varies between 400 and 500 in flat countries.

The application of the Dickens formula, which is perhaps the most conservative, to Nebraska streams would give the following rates of discharge, the coefficient used being 200: Elkhorn River at mouth, 5,980 square miles, 139,000 second-feet; Loup River at mouth, 13,540 square miles, 250,000 second-feet; Republican River at Superior, 22,350 square miles, 366,000 second-feet. If such quantities of water should ever come down these rivers the damage to life and property would be incalculable. The maximum recorded discharges are, for the Elkhorn, 9,600 second-feet; the Loup, 26,000 second-feet; the Republican, 25,000 second-feet.

It may be contended that these formulas were never intended to apply to such large areas in dry countries; but Salt River, of Arizona, with a drainage area at Phoenix of 12,260 square miles, largely steep, bare slopes, had a maximum observed discharge in 1891 of about 300,000 second-feet, which would fall very near Dickens's curve. When it is realized that Platte and Republican rivers go entirely dry and that the Niobrara and Loup have a minimum flow of about 0.1 second-foot per square mile of drainage area under practically the same conditions of rainfall, the absurdity of attempting to apply to these streams any formula for minimum rate determination is at once apparent.

DETERMINATION OF MEAN ANNUAL RUN-OFF.

A quantitative determination of the total yield of a drainage basin during distinct climatological periods of time can often be approximately estimated, provided average or normal values are used for such periods. Moreover, the determination of stream flow from rainfall records must legitimately be limited to this problem on account of the large debits and credits at the beginning and end of short periods of time. To illustrate: The percentage of rainfall appearing as run-off in a single month will depend, among other things, on the saturated condition of the soil at the beginning of the month. If the ground water is depleted, a large part of the precipitation will go to augment the ground storage; if, on the other hand, the ground water present is greater than the normal quantity, a much larger percentage of precipitation will run off from the watershed. Again, if a heavy rainfall appears at the end of the month the total run-off for that month may be very low and the rainfall comparatively high, while in the following month the conditions would be reversed. It is therefore necessary to con-

sider longer periods of time, and for convenience the year is divided into two seasons designated the "open season," from April to October, inclusive, and the "closed season," from November to March, inclusive. In the plains of the Middle West, on account of uncertain ice conditions it is impossible without great expense to obtain stream-flow data during the closed season, hence the discharge of Nebraska streams is known only for the open season. In 1897 daily discharges were tabulated during the closed season for Nebraska stations from rating curves developed during the open season, but they are not only incorrect, but grossly misleading. The writer has seen Platte River frozen practically solid to the bed, when the position of the water on the gage, according to the open season rating curve, indicated a discharge of 4,000 or 5,000 second-feet. As a matter of fact, there was less than 100 second-feet trickling along under the ice.

SPRING FLOODS ON PLATTE RIVER.

It is popularly believed that the magnitude of the periodic spring floods on Platte River depends entirely on the quantity of snowfall on its headwaters during the preceding winter, but this is only partly true. There are so many other factors, such as the conditions of the soil saturation and the manner in which the winter snows are melted, that the relation between these quantities is not at once apparent. In the following table the total run-off, as measured at North Platte for the flood period of each year, April to July, inclusive, is compared with the total precipitation on the drainage basin above that point for the preceding winter season, November to March, inclusive.

Winter snowfall on headwaters of North Platte River and run-off during following spring flood period, at North Platte, 1894–1906.

Year.	Precipitation November to March.	Departure from average.	Run-off April to July.	Departure from average.	Year.	Precipitation November to age.	Departure from average.	Run-off April to July.	Departure from average.
1894–5	3.10	+0.16	0.99	0.0	1901–2	3.24	+0.30	0.61	−0.38
1895–6	3.06	+ .12	.57	− .42	1902–3	3.59	+ .65	.74	− .25
1896–7	3.24	+ .30	1.46	+ .47	1903–4	1.46	−1.48	.86	− .13
1897–8	2.73	− .21	.66	− .33	1904–5	2.28	− .66	1.38	+ .39
1898–9	5.00	+2.06	1.62	+ .63	1905–6	3.02	+ .08	1.13	+ .14
1899–1900	1.89	−1.05	1.05	+ .06					
1900–1	2.69	− .25	.84	− .15	Average	2.94	.....	.99	.....

It will be noted that in 1896 the run-off was only about half the average for the twelve years, although the precipitation was above the average. This is explained by the fact that during the three preceding years—1893 to 1895, inclusive (see Table 1, p. 28)—the precipitation throughout Nebraska and neighboring States was far below the normal, and the ground water was so greatly depleted that the larger precipitation in 1896 was used up in restoring the

ground water more nearly to its normal condition and therefore did not appear in the stream. The maximum precipitation and run-off occurred simultaneously in 1898–9 and no doubt resulted in an abnormal amount of ground storage, so that during the following season, in spite of the fact that the precipitation was only about half the average, the run-off was above the normal. The excessive floods which occurred in the summer of 1905 (see discharge table for Platte River, p. 54, and Pl. I) were evidently not caused

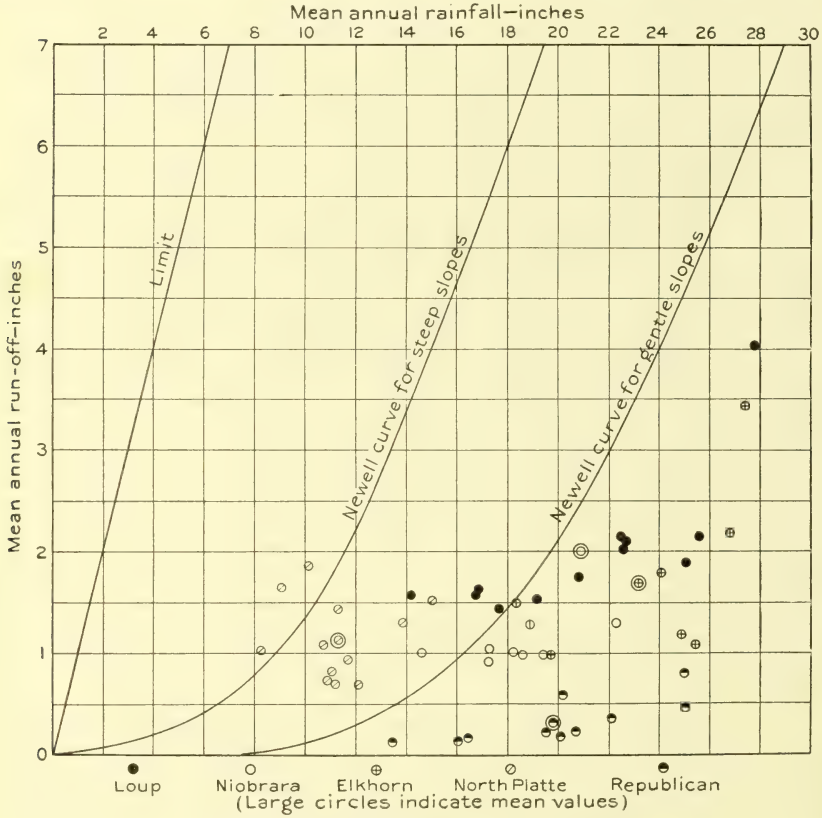


FIGURE 5.—Relation of rainfall to run-off in Nebraska.

solely by snowfall in the mountains, as the precipitation for the preceding winter was far below the normal.

The relation between annual run-off and annual precipitation has been graphically expressed by F. H. Newell in the form of a set of curves, now known as the "Newell curves." These curves are reproduced in figure 5, on which are also platted the run-off in inches as measured at gaging stations on Elkhorn River at Norfolk, Niobrara River near Valentine, Loup River at Columbus, North Platte River at North Platte, and Republican River at Bostwick, with the corresponding precipitation in inches on their drainage basins, taken

A

B

FLOOD SCENES AT LINCOLN.

from records of the United States Weather Bureau. It is true that the run-off here plotted is only for the open season, but the precipitation for the same period is used. If complete yearly records of run-off were available and corresponding yearly values of precipitation were used, the relative positions of the points would not be materially altered, as each point would then appear above and to the right of the position now occupied. Moreover, the distance they would appear to the right of their present positions would be small compared with the distance they would be moved upward, for the reason that the precipitation during the winter months is a very small proportion of the annual amount (see Table 7, p. 32); but this difference does not exist for the run-off factor. In other words, the percentage of precipitation appearing as run-off is much greater in winter than during the remainder of the year. If records were complete, it is believed that the mean annual values for Loup and Niobrara rivers would not fall far short of the curve for gentle slopes. The agreement is not so apparent with the other streams.

AVAILABLE DATA FOR DETERMINING RUN-OFF.

As a guide to the quantitative determination of run-off for streams other than those investigated by the United States Geological Survey, existing under similar climatic conditions, there is presented herewith a summary of such data collected on Nebraska streams as are sufficiently reliable to justify their use in this connection. Table 1 (p. 28), copied from the annual summary for 1906 of the Nebraska section of the climatological service of the Weather Bureau, gives the monthly, annual, and seasonal precipitation for the entire State, with departures from the normal. The normal rainfall for the crop season, April to August, inclusive, is 69 per cent of the annual.

Tables 2 to 6 give the total monthly precipitation on the drainage areas of North Platte, Republican, Loup, Niobrara, and Elkhorn rivers, respectively, for the twelve years 1895 to 1906, inclusive, together with the normal amounts compiled from records of much longer duration. Each figure in the table is a mean value obtained from a number of well-distributed stations through the basin. The precipitation in Nebraska decreases from east to west at the rate of about 4½ inches per hundred miles. It is therefore necessary to avoid giving too much weight to the records from the eastern portions of the drainage basins, though more of them are available than from the western portions; that is to say, the rainfall as measured at any station should be weighted according to the area served by that station, an indeterminate factor, or care should be taken to choose stations that serve similar areas. Where records for any station were incomplete those for an adjoining station have been used.

TABLE 1.—*Monthly, annual, and seasonal precipitation for Nebraska, with departures from the normal, 1876–1906.*

Year.	Jan.		Feb.		Mar.		Apr.		May.		June.		July.		Aug.		Sept.		Oct.		Nov.		Dec.		Annual.		Crop season, Apr.–Aug.	
	Precipitation.	Departure.	Precipitation.	Departure.	Precipitation.	Departure.	Precipitation.	Departure.	Precipitation.	Departure.	Precipitation.	Departure.	Precipitation.	Departure.	Precipitation.	Departure.	Precipitation.	Departure.	Precipitation.	Departure.	Precipitation.	Departure.	Precipitation.	Departure.	Precipitation.	Departure.	Precipitation.	Departure.
Normal	0.60	.....	0.69	.....	1.15	.....	2.57	.....	3.69	.....	3.89	.....	3.56	.....	2.76	.....	2.09	.....	1.62	.....	0.68	.....	0.65	.....	23.94	.....	16.47	.....
1876	.20	−0.40	.55	−0.14	1.85	+0.70	1.45	−1.12	2.54	−1.15	1.99	−1.90	4.28	+0.72	3.25	+0.49	3.63	+1.54	.98	−0.64	1.68	+1.00	.24	−0.41	22.64	− 1.30	13.51	−2.96
1877	.98	+ .38	.31	− .38	.76	− .39	2.86	+ .29	5.79	+2.10	3.50	− .39	1.45	−2.11	2.04	− .72	2.06	− .03	2.92	+1.30	.82	+ .14	1.85	+1.20	25.34	+ 1.40	15.64	− .83
1878	.44	− .16	.31	− .38	1.95	+ .80	1.85	− .72	4.09	+ .40	5.19	+1.30	5.71	+2.15	2.16	− .60	1.90	− .19	.39	−1.23	.64	− .04	.44	− .21	25.07	+ 1.13	19.00	+2.53
1879	.80	+ .20	.80	+ .11	.70	− .45	2.61	+ .04	3.43	− .26	4.27	+ .38	5.92	+2.36	1.54	−1.22	1.40	− .69	1.03	− .59	1.31	+ .63	.58	− .07	24.39	+ .45	17.77	+1.30
1880	.38	− .22	.18	− .51	.50	− .65	.72	−1.85	2.11	−1.58	4.44	+ .55	3.36	− .20	3.87	+1.11	2.74	+ .65	1.78	+ .16	.53	− .15	.62	− .03	21.23	− 2.71	14.50	−1.97
1881	.91	+ .31	1.64	+ .95	1.51	+ .36	2.02	− .55	6.28	+2.59	5.36	+1.47	3.38	− .18	1.18	−1.58	3.77	+1.68	3.42	+1.80	.87	+ .19	.57	− .08	30.91	+ 6.97	18.22	+1.75
1882	.56	− .04	.63	− .06	.15	−1.00	3.58	+1.01	4.93	+1.24	4.34	+ .45	3.40	− .16	1.31	−1.45	.92	−1.17	2.23	+ .61	.45	− .23	1.01	+ .36	23.51	− .43	17.56	+1.09
1883	1.04	+ .44	.92	+ .23	.50	− .65	2.79	+ .22	5.39	+1.70	7.18	+3.29	2.81	− .75	3.21	+ .45	2.04	− .05	3.58	+1.96	.24	− .44	1.04	+ .39	30.74	+ 6.80	21.38	+4.91
1884	.46	− .14	.69	− .00	1.96	+ .81	2.60	+ .03	3.06	− .63	2.04	−1.85	5.79	+2.23	2.97	+ .21	1.66	− .43	1.71	+ .09	.16	− .52	.90	+ .25	24.00	+ .06	16.46	− .01
1885	.51	− .09	.84	+ .15	.46	− .69	3.30	+ .73	3.73	+ .04	3.66	− .23	4.32	+ .76	3.48	+ .72	1.76	− .33	1.80	+ .18	1.18	+ .50	.94	+ .29	25.98	+ 2.04	18.49	+2.02
1886	1.21	+ .61	.84	+ .15	2.01	+ .86	2.64	+ .07	3.39	− .30	2.96	− .93	1.84	−1.72	3.22	+ .46	2.69	+ .60	.86	− .76	1.24	+ .56	.81	+ .16	23.71	− .23	14.05	−2.42
1887	.49	− .11	.78	+ .09	.39	− .76	2.32	− .25	2.27	−1.42	3.22	− .67	3.10	− .46	4.13	+1.37	4.09	+2.00	.88	− .74	.61	− .07	.71	+ .06	22.99	− .95	15.04	−1.43
1888	.47	− .13	.74	+ .05	2.13	+ .98	2.39	− .18	5.83	+2.14	3.11	− .78	3.10	− .46	3.11	+ .35	.38	−1.71	.93	− .69	.22	− .46	.45	− .20	22.86	− 1.08	17.54	+1.07
1889	.91	+ .31	.29	− .40	1.06	− .09	2.33	− .24	2.69	−1.00	3.55	− .34	5.77	+2.21	2.40	− .36	1.48	− .61	.93	− .69	.86	+ .18	.37	− .28	22.64	− 1.30	16.74	+ .27
1890	.78	+ .18	.36	− .33	.84	− .31	1.97	− .60	2.34	−1.35	3.63	− .26	2.10	−1.46	2.24	− .52	.99	−1.10	.93	− .69	.87	+ .19	.13	− .52	17.18	− 6.76	12.28	−4.19
1891	1.43	+ .83	1.13	+ .44	1.86	+ .71	3.14	+ .57	2.90	− .79	7.07	+3.18	5.48	+1.92	2.92	+ .16	1.28	− .81	1.96	+ .34	.32	− .36	1.13	+ .48	30.62	+ 6.68	21.51	+5.04
1892	.86	+ .26	.99	+ .30	1.62	+ .47	4.00	+1.43	5.63	+1.94	2.18	−1.71	2.57	− .99	3.20	+ .44	.48	−1.61	1.71	+ .09	.27	− .41	.61	− .04	24.12	+ .18	17.58	+1.11
1893	.13	− .47	.84	+ .15	1.32	+ .17	1.25	−1.32	2.66	−1.03	3.10	− .79	2.62	− .94	2.33	− .43	1.02	−1.07	.31	−1.31	.33	− .35	.89	+ .24	16.80	− 7.14	11.96	−4.51
1894	.60	.00	.58	− .11	.90	− .25	1.97	− .60	.91	−2.78	3.19	− .70	1.43	−2.13	.74	−2.02	1.21	− .88	1.21	− .41	.13	− .55	.43	− .22	13.30	−10.64	8.24	−8.23
1895	.36	− .24	.80	+ .11	.72	− .43	2.28	− .29	2.40	−1.29	4.67	+ .78	1.73	−1.83	3.04	+ .28	1.39	− .70	.22	−1.40	.94	+ .26	.15	− .50	18.70	− 5.24	14.12	−2.35
1896	.37	− .23	.16	− .53	1.45	+ .30	4.82	+2.25	4.03	+ .34	4.04	+ .15	3.87	+ .31	1.81	− .95	2.37	+ .28	1.83	+ .21	1.21	+ .53	.23	− .42	26.17	+ 2.23	18.57	+2.10
1897	.79	+ .19	.59	− .10	1.49	+ .34	3.82	+1.25	1.66	−2.03	3.60	− .29	2.57	− .99	2.60	− .16	1.26	− .83	3.34	+1.72	.51	− .17	1.31	+ .66	23.54	− .40	14.25	−2.22
1898	.67	+ .07	.43	− .26	.61	− .54	2.14	− .43	4.86	+1.17	3.54	− .35	2.12	−1.44	2.24	− .52	2.30	+ .21	.90	− .72	.57	− .11	.32	− .33	20.70	− 3.24	14.90	−1.57
1899	.24	− .36	.61	− .08	.92	− .23	.99	−1.58	3.71	+ .02	3.83	− .06	2.87	− .69	3.26	− .50	.46	−1.63	1.00	− .62	.88	+ .20	.84	+ .19	19.51	− 4.43	14.66	−1.81
1900	.07	− .53	1.07	+ .38	.62	− .53	4.68	+2.11	2.32	−1.37	2.50	−1.39	4.54	+ .98	3.46	+ .70	2.66	+ .57	2.08	+ .46	.15	− .53	.31	− .34	24.46	+ .52	17.50	+1.03
1901	.17	− .43	.83	+ .14	1.90	+ .75	2.32	− .25	1.86	−1.83	4.54	+ .65	1.59	−1.97	2.25	− .51	4.55	+2.46	1.64	+ .02	.50	− .18	.60	− .05	22.76	− 1.18	12.56	−3.91
1902	.64	+ .04	.39	− .30	1.18	+ .03	1.07	−1.50	4.14	− .45	5.12	+1.23	5.93	+2.37	3.25	+ .49	3.54	+1.45	1.92	+ .30	.52	− .16	1.40	+ .75	29.09	+ 5.15	19.51	+3.04
1903	.22	− .38	1.42	+ .73	.72	− .43	1.80	− .77	7.27	+3.58	2.21	−1.68	4.94	+1.38	5.05	+2.29	1.52	− .57	1.25	− .37	.77	+ .09	.10	− .55	27.27	+ 3.33	21.27	+4.80
1904	.35	− .25	.13	− .56	.53	− .62	2.00	− .57	3.68	− .01	4.71	+ .82	4.44	+ .88	2.80	+ .04	1.98	− .11	2.44	+ .82	.11	− .57	.20	− .45	23.37	− .57	17.63	+1.16
1905	1.07	+ .47	.76	+ .07	1.31	+ .16	3.70	+1.13	5.73	+2.04	5.04	+1.15	4.67	+1.11	2.79	+ .03	3.79	+1.70	1.23	− .39	1.53	+ .85	.02	− .63	31.65	+ 7.71	21.93	+5.46
1906	.46	− .14	.64	− .05	1.87	+ .72	4.35	+1.78	2.76	− .93	2.70	−1.19	2.70	− .86	3.66	+ .90	3.33	+1.24	2.85	+1.23	.64	− .04	1.04	+ .39	26.98	+ 3.04	16.17	− .30

TABLE 2.—*Precipitation in drainage basin of North Platte River above North Platte, 1895–1906.*

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.45	0.54	0.93	1.86	2.44	2.11	1.93	1.32	0.90	0.71	0.36	0.47	13.95
1895	.60	.37	.55	.69	1.71	3.36	1.26	.77	.25	.23	.65	.23	10.67
1896	.64	.34	1.00	1.83	2.17	2.65	1.88	1.12	.57	.70	.45	.05	13.40
1897	.37	.47	1.76	1.41	1.37	1.26	1.55	1.96	.47	1.07	.60	.74	13.03
1898	.80	.23	.79	1.12	4.34	1.75	1.68	.83	.78	.63	.74	.39	14.08
1899	.80	.83	1.64	.79	3.18	1.67	1.55	1.23	.51	1.22	.45	.41	14.28
1900	.05	.95	.29	4.34	.91	.81	2.39	.58	1.19	.54	.20	.44	12.69
1901	.04	.56	1.00	2.06	2.78	2.66	.75	1.17	1.09	.87	.25	.88	14.11
1902	.24	.49	1.12	1.26	2.47	2.70	1.75	.99	2.10	.90	.14	.94	15.10
1903	.19	.91	.98	1.33	2.03	1.71	2.11	1.79	1.56	.51	.26	.22	13.60
1904	.24	.25	.75	.99	2.87	2.97	1.86	.92	1.09	.99	.02	.21	13.16
1905	1.04	.52	.77	3.45	3.43	2.11	2.67	1.25	1.32	.82	.62	.14	18.24
1906	.54	.31	2.31	1.93	2.63	1.71	1.46	2.04	1.98	2.07	.87	.71	18.59

TABLE 3.—*Precipitation in drainage basin of Republican River above Bostwick, 1895–1906.*

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.44	0.79	1.09	2.73	3.30	3.85	3.83	2.39	1.90	1.18	0.52	0.48	22.12
1895	.51	1.11	.24	2.28	2.64	3.89	3.29	2.35	.72	.26	.87	.16	18.34
1896	.39	.11	.96	5.17	3.34	3.55	2.69	2.64	1.87	1.44	.59	.13	22.88
1897	.39	.61	1.95	3.95	1.22	4.58	2.12	3.05	1.40	3.81	.35	.95	24.38
1898	.37	.13	.35	2.77	4.72	3.35	2.17	1.55	4.13	.88	.55	.31	21.28
1899	.57	.51	.86	.65	2.94	3.74	3.67	1.79	.22	.42	.24	.48	16.09
1900	.04	1.45	.80	4.45	1.50	2.42	3.05	2.28	1.54	.87	.28	.27	18.95
1901	.17	.82	3.16	3.28	.96	3.13	1.10	3.35	3.97	.75	.28	.57	21.36
1902	.42	.50	1.14	.86	5.52	4.67	5.41	2.35	4.01	2.22	.14	1.04	28.28
1903	.26	2.14	.41	1.38	7.14	1.85	4.67	3.61	.53	1.08	.70	.02	23.59
1904	.08	.26	.27	2.78	3.37	5.48	3.23	2.82	1.83	2.61	.07	.25	23.05
1905	.63	.66	1.76	3.70	4.56	4.63	6.53	1.98	2.45	1.03	1.03	.01	28.97
1906	.48	.47	2.21	4.92	1.87	2.02	2.99	2.89	2.04	2.53	.67	.48	23.47

TABLE 4.—*Precipitation in drainage basin of Loup River above Columbus, 1895–1906.*

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.48	0.58	1.09	2.88	3.18	4.16	3.59	2.36	2.03	1.39	0.48	0.47	22.70
1895	.18	.85	.79	2.06	2.48	4.76	.98	2.49	1.81	.20	.84	.12	17.30
1896	.41	.06	1.50	4.84	2.54	4.94	4.12	.89	2.10	1.40	.87	.14	23.55
1897	.67	.44	1.68	3.88	1.26	4.11	2.53	2.96	1.16	3.02	.46	1.40	22.39
1898	.83	.23	.26	1.66	5.04	2.34	2.88	2.84	1.35	.83	.43	.19	18.92
1899	.16	.46	.68	.98	2.91	3.92	2.47	2.93	.70	.29	.57	.99	16.56
1900	.03	1.01	.35	4.47	2.57	2.30	5.50	3.67	2.41	1.72	.17	1.30	24.35
1901	.08	.75	1.37	1.92	1.61	4.92	.90	1.58	4.89	1.93	.60	.51	21.05
1902	.52	.48	1.51	1.42	4.27	4.45	6.29	3.77	3.44	1.95	.24	1.13	29.45
1903	.22	1.54	.72	1.56	5.46	1.68	6.88	5.01	.87	1.00	.51	.15	25.62
1904	.44	.09	.22	1.57	4.10	5.53	6.13	2.41	2.24	3.08	.07	.16	26.14
1905	1.21	.66	.93	4.15	6.54	6.07	4.58	1.93	3.81	.74	1.16	.08	31.88
1906	.55	.32	1.32	5.47	2.89	2.06	2.74	3.52	2.94	3.12	.93	1.27	27.03

TABLE 5.—*Precipitation in drainage basin of Niobrara River above Valentine, 1895–1906.*

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.67	0.70	1.43	2.31	2.97	3.09	2.74	2.05	1.12	1.09	0.51	0.61	19.20
1895	.50	.45	2.14	2.99	1.94	3.78	1.11	.71	.78	.10	.80	.12	15.43
1896	.58	.34	1.89	2.44	1.45	3.63	2.90	.60	2.35	.95	1.39	.20	18.72
1897	1.64	.70	1.58	1.51	1.85	2.12	3.89	2.20	.37	1.17	1.23	1.46	19.98
1898	1.01	.26	.85	1.08	6.40	1.63	2.98	1.57	.85	.24	.54	.48	17.65
1899	.42	.56	2.06	1.00	2.60	2.48	1.77	2.70	.25	.94	.26	.70	15.76
1900	.09	1.10	.89	4.01	2.49	2.42	5.74	3.55	1.52	1.45	.15	.64	25.05
1901	.03	1.35	1.66	1.45	1.32	7.02	1.49	2.44	3.38	2.31	.03	.95	23.43
1902	.46	1.22	1.84	1.08	2.60	3.73	2.26	2.77	1.34	.80	.41	1.85	19.96
1903	.50	1.31	.81	1.72	3.27	1.66	5.74	2.81	1.52	.63	.09	.23	20.29
1904	.60	.24	.28	.70	2.68	5.08	3.00	2.56	1.93	1.28	.08	.23	18.64
1905	1.03	.26	1.09	2.90	5.24	5.79	4.51	1.69	.97	1.16	.50	.16	25.30
1906	.54	.44	1.55	2.10	3.22	2.22	1.47	3.58	3.02	2.99	.60	.81	22.54

TABLE 6.—*Precipitation in drainage basin of Elkhorn River above Norfolk, 1895–1906.*

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.43	0.62	1.13	2.95	3.80	4.15	3.73	3.08	2.48	1.63	0.59	0.61	25.26
1895	.22	.29	1.38	4.78	3.11	6.34	.65	4.05	2.51	.03	.68	.04	24.08
1896	.24	.04	1.05	6.57	2.53	5.21	5.22	1.25	2.47	2.24	2.19	.10	29.11
1897	1.21	.47	1.67	4.02	1.17	3.65	2.74	2.77	2.09	3.05	.34	1.46	24.64
1898	.54	.63	.72	1.59	4.97	4.56	2.54	2.42	1.23	1.09	.35	.30	20.95
1899	.10	.52	.66	1.01	5.72	4.67	2.66	3.06	1.04	.72	.74	.75	21.65
1900	.09	.96	.93	5.21	3.05	2.10	4.62	3.53	3.29	3.12	.19	.27	27.36
1901	.07	.56	1.41	2.06	2.46	8.37	.58	.96	7.62	2.05	1.07	.71	27.92
1902	.61	.35	1.37	1.86	2.71	5.51	6.61	4.57	4.75	.81	.18	1.51	30.44
1903	.18	1.16	1.25	2.35	7.22	2.88	6.50	5.52	1.14	1.80	1.09	.14	31.23
1904	.34	.40	.34	1.61	3.74	5.35	4.44	3.70	1.85	4.85	.17	.31	29.29
1905	.98	.76	1.43	3.30	8.51	5.00	3.04	2.26	6.01	1.42	1.70	0	34.45
1906	.34	.90	.99	4.95	3.29	3.22	1.62	3.47	5.18	3.54	.83	1.22	29.55

From the foregoing precipitation tables and from discharge data collected in the State, Table 7 has been prepared. This table gives the total run-off as measured at the gaging stations on North Platte River at North Platte, Republican River at Bostwick or Superior, Loup River at Columbus, Niobrara River near Valentine, and Elkhorn River at Norfolk, for the seven months of the open season, from April to October, inclusive. This run-off is given both in inches of depth and in percentages of the rainfall on the respective catchment areas for the corresponding period. The rainfall is given both in inches of depth for the season and in percentages of the total annual amounts. It will be noticed that for five winter months the precipitation is only 15 per cent of that for the entire year. The average run-off during the seven months of the open season on North Platte and Loup rivers is 10 per cent of the precipitation for the corresponding period; Niobrara River indicates only 6 per cent, but the record is only half as long as that of the other streams; the Elkhorn discharges 8 per cent; the Republican appears to be in a class by itself, discharging less than 2 per cent of the pre-

cipitation on its drainage area. The rainfall and run-off from the upper portion of this table have been plotted in figure 5.

Table 7 gives also the mean monthly precipitation and run-off from the same stations. Twelve-year averages were available for North Platte and Loup rivers, eleven for the Republican, eight for the Elkhorn, and six for the Niobrara. For the mean monthly rainfall normal values from Tables 2 to 6 were used.

Elkhorn River is wholly in Nebraska. Its drainage area is rolling, broken in places, and largely cultivated or grass grown. It heads in the sand hills of Rock County.

The Niobrara and Loup drainage areas are similar in character and consist largely of rolling sand hills; they are given over to range land or, where the soil is firm, cultivated in small tracts. The sand areas are the controlling features of these streams, as the precipitation thereon is absorbed by the sand and gradually fed to the stream in the form of springs. Their drainage areas thus act in themselves as conserving reservoirs, and to this fact alone is due the remarkable constancy of flow observed on both rivers.

North Platte River partakes of the nature of a mountain stream and a river of the plains. It rises in northern Colorado, drains a large mountainous area in Wyoming, and traverses Nebraska on a bed of sand. It receives no large tributaries after leaving Wyoming. Its drainage area in Nebraska is rolling range land with cultivated valleys.

The Republican is not unlike the North Platte, except that it has not the mountainous headwater country. In Colorado its drainage basin is made up of table-lands broken by canyons and gullies and interspersed with low hills and rocky scab land. In Nebraska it drains a considerable area of sand hills, which, however, is only a small portion of the entire catchment basin.

TABLE 7.—*Rainfall and run-off on Nebraska streams, 1895–1906.*

BY YEARS, FOR THE SEASON, APRIL TO OCTOBER, INCLUSIVE.

Date.	North Platte.				Republican.				Loup.				Niobrara.				Elkhorn.			
	Rainfall.		Run-off.		Rainfall.		Run-off.		Rainfall.		Run-off.		Rainfall.		Run-off.		Rainfall.		Run-off.	
	Inches.	Per cent of annual.	Inches.	Per cent of rainfall.	Inches.	Per cent of annual.	Inches.	Per cent of rainfall.	Inches.	Per cent of annual.	Inches.	Per cent of rainfall.	Inches.	Per cent of annual.	Inches.	Per cent of rainfall.	Inches.	Per cent of annual.	Inches.	Per cent of rainfall.
1895	8.27	77	1.04	13	15.33	84	.....	.....	16.78	97	1.58	9	11.41	74	.....	.....	21.47	89	.....	.....
1896	10.92	81	.74	7	20.70	90	0.23	1.1	20.83	88	1.74	8	14.42	77	.....	.....	25.49	88	1.08	4
1897	9.09	70	1.64	18	20.13	82	.17	.8	18.92	85	1.52	8	13.21	67	.....	.....	19.49	79	.99	5
1898	11.13	79	.70	6	19.57	92	.22	1.1	16.94	90	1.63	10	14.75	83	.....	.....	18.40	88	1.49	8
1899	10.15	71	1.86	18	13.43	84	.12	.9	14.20	86	1.57	11	11.74	75	.....	.....	18.88	87	1.28	7
1900	10.76	85	1.09	10	16.11	85	.12	.7	22.64	93	2.02	9	21.18	85	.....	.....	24.92	91	1.17	5
1901	11.38	81	.94	8	16.54	77	.16	1.0	17.75	84	1.44	8	19.41	83	0.98	5	24.10	86	1.79	7
1902	12.17	81	.68	6	25.04	89	.46	1.8	25.59	87	2.15	8	14.58	73	.99	7	26.82	88	2.17	8
1903	11.04	81	.82	7	20.24	86	.58	2.9	22.46	88	2.15	9	17.35	85	1.04	6	27.41	88	3.42	12
1904	11.69	86	.94	8	22.12	96	.35	1.6	25.06	96	1.89	7	17.23	93	.91	5	25.54	87	.....	.....
1905	15.05	82	1.51	10	24.88	86	.82	3.3	27.82	87	4.03	14	22.26	88	1.24	6	29.54	86	.....	.....
1906	13.82	75	1.30	9	19.26	82	.31	1.6	22.74	84	2.10	9	18.59	82	.99	5	25.28	86	.....	.....
Average[a]	11.29	80	1.11	10	18.82	87	.32	1.7	20.92	86	1.98	10	18.24	80	1.02	6	23.20	86	1.67	8
MONTHLY AVERAGES FOR TERM OF YEARS.																				
April	1.86	.....	.15	8	2.73	.....	.04	1.5	2.88	.....	.30	10	2.31	.....	.17	7	2.95	.....	.27	9
May	2.44	.....	.31	13	3.30	.....	.07	2.1	3.18	.....	.31	10	2.97	.....	.15	5	3.80	.....	.34	9
June	2.11	.....	.39	18	3.85	.....	.05	1.3	4.16	.....	.32	8	3.09	.....	.14	5	4.15	.....	.36	9
July	1.93	.....	.15	8	3.83	.....	.08	2.1	3.59	.....	.27	8	2.74	.....	.16	6	3.73	.....	.23	6
August	1.32	.....	.05	4	2.39	.....	.05	2.1	2.36	.....	.28	12	2.05	.....	.14	7	3.08	.....	.17	6
September	.90	.....	.02	2	1.90	.....	.02	1.1	2.03	.....	.23	11	1.12	.....	.13	12	2.48	.....	.14	6
October	.71	.....	.04	6	1.18	.....	.02	1.7	1.39	.....	.25	18	1.09	.....	.14	13	1.63	.....	.17	6

[a] Average for rainfall obtained from those years covered by run-off records.

CONCLUSIONS.

The streams of the western plains differ markedly with respect to the relation between rainfall and run-off from streams in other portions of the United States, and formulas elsewhere applicable are wholly inadequate and may lead to gross errors.

Formulas for maximum and minimum discharge are worthless.

The magnitude of spring floods in Platte River is not always dependent on the snowfall in Wyoming during the preceding winter.

The run-off during the winter months can not be estimated by the use of precipitation records. Considerable time was spent in an endeavor to determine rational values for winter flow from winter records of precipitation. It is undoubtedly true that a much larger percentage of the precipitation appears as run-off in winter than during the remainder of the year, but just what the ratio of the percentages of rainfall for the two periods is can not be determined.

OUTLINE OF HYDROGRAPHIC DATA.

The following pages contain a compilation of all hydrographic data collected in Nebraska to and including the year 1906. These data are arranged according to the principal drainage basins of the State in the following order: Platte River, Republican River, Niobrara River, White River, and Hat Creek basins. The stations at which the volume of stream flow has been investigated are arranged in order from the headwaters toward the mouth. Those on the main stream are presented first, and are followed by the stations on tributaries arranged in the same order.

For each drainage basin there are given: (1) A brief description of the area drained; (2) hydrographic data for all stations where discharges have been obtained; (3) a table of miscellaneous measurements made at points other than at regular gaging stations; (4) precipitation tables for representative rainfall stations within the area, taken from records of the Weather Bureau.

A "regular station" is one at which equipment was installed to obtain daily discharges. For each regular station there is given: (1) A description, with sufficient information to enable anyone to use the equipment and thereby make comparisons with results herein presented; (2) a table of discharge measurements; (3) mean daily gage heights; (4) tables of daily discharge, where such were obtained, arranged in chronological order; (5) estimated monthly discharges, arranged so that all monthly estimates are readily comparable. These tables give maximum, minimum, and mean discharge in second-feet for the month, total run-off in acre-feet, mean discharge or run-off in second-feet per square mile of drainage area, monthly run-off in inches of depth, rainfall in inches on the drainage area above

that point, and run-off in percentages of the rainfall. For incomplete months the discharges and run-off in acre-feet are given only for the actual number of days noted. Where the record for the month lacked only a few days and those not at critical stages, the mean discharge obtained for the days on which gage heights were reported has been used as the mean for the entire month. On account of the unstable character of the stream beds, mean velocities and cross-sectional areas are of little general value, and they have not been given in the table of discharge measurements. As most of the discharges herein have been obtained by the indirect method (see pp. 9–15), the rating tables would not be of value unless accompanied by tedious and lengthy explanations. They have therefore been omitted.

EVAPORATION AND SEEPAGE NEAR KEARNEY.

Observations of evaporation and seepage were made during 1896 on a small pond on the grounds of the Nebraska State Industrial School at Kearney. The pond is 320 feet long in a north-south direction and about 90 feet wide east and west. When it is full the water is nearly 7 feet deep, and is usually from 5 to 5.5 feet. Fluctuations of the water surface were read by means of a hook gage reading to hundredths of an inch. The water supply, except that which falls in the form of rain and snow upon the surface of the pond and the inner slopes of the embankment, is under complete control, being admitted from the Kearney canal through a cast-iron pipe with a gate valve. The following table summarizes the results obtained:

Estimated monthly evaporation and seepage near Kearney, 1896.

Month.	Inches per 24 hours.			Total (inches).	Month.	Inches per 24 hours.			Total (inches).
	Maximum.	Minimum.	Mean.			Maximum.	Minimum.	Mean.	
April 19–30	1.70	0.95	1.25	15.00	August	3.39	1.31	2.25	69.75
May	2.73	.62	1.25	38.75	September	3.04	1.16	1.85	55.50
June	2.10	.70	1.15	34.50	October	2.59	1.02	1.45	44.95
July	3.72	.80	1.75	54.25	November	2.55	.80	1.32	39.60

PLATTE RIVER DRAINAGE BASIN.

PLATTE RIVER PROPER.

DESCRIPTION OF BASIN.

The Platte proper is formed by the junction of North and South Platte rivers, near the center of Lincoln County, whence it flows southeast, then northeast, then east, emptying into the Missouri about 18 miles below Omaha. Its drainage basin embraces almost the entire central portion of the State and large areas in Wyoming and Colorado.

From its source in Lincoln County to a point near Ashland, in Saunders County, the Platte is a broad, shallow stream, flowing in many places as a network of interlacing channels among numerous islands and sand bars (Pl. II). Its basin lies wholly north of a line closely bordering the south bank of the stream, and is generally rolling prairie land in the middle portion, which gives way in the western and northern portions to extensive areas of sand hills. Along the main stream and its tributaries is a deep flood plain of alluvium, composed of loam, sand, and gravel in the valleys and talus on the slopes. Outside of this flood plain the soil is mostly loess, consisting of yellow clays and fine sandy loam. In the western areas there is little or no forest or timber land except in the immediate valleys of the small tributaries; but farther east there are comparatively large areas of timber land, some native and some planted, and the stream is changed in character, being confined between heavily wooded limestone bluffs. The country is almost wholly given to cattle raising in the western portions and to agriculture in the eastern.

The precipitation has a mean value of 23.33 inches, of which 69 per cent falls during the five months of the growing season, April to August; about half of the remainder is snowfall. The evaporation averages about 4½ feet.

The principal tributaries of the Platte are the Elkhorn and the Loup, both draining the country to the north of the river.

The Platte is subject to periodic floods caused by melting snows in the headwaters of the North and South Platte, which reach a maximum in June or July, often doing considerable damage to property on the lower portion of the stream. The waters of the river in the western part are extensively used for irrigation.

Gaging stations have been maintained in the drainage basin of Platte River in Nebraska as follows:

Gaging stations in Platte River basin.

River.	Station.	County.	Established.	Discontinued.
Platte	Lexington	Platte	Apr. 2, 1902	
Do	Columbus	do	June 4, 1895	
Do	South Bend	Cass	Mar. 25, 1903	Sept. 30, 1903
Loup	Columbus	Platte	Oct. 13, 1894	
North Loup	St. Paul	Howard	May 5, 1895	[a] Nov. 30, 1903
Middle Loup	do	do	do	Do.
Elkhorn	Norfolk	Madison	July 16, 1896	Nov. 21, 1903
Do	Arlington	Washington	Apr. 28, 1898	Do.

[a] Observations suspended during 1898, 1900, 1901, and 1902.

PLATTE RIVER NEAR LEXINGTON.

The station near Lexington was established April 2, 1902, and has been maintained continuously since that date, except during the closed winter months. It is located at a highway bridge 3 miles

south of Lexington, in sec. 20, T. 9 N., R. 21 W., and is shown on the Lexington atlas sheet of the United States Geological Survey.

The section of the river at the gaging station is straight. The bed is of shifting sand and the banks are low. The stream flows in two channels; the smaller one is about one-fourth mile south of the main channel and is measured from a similar pile bridge. There are no obstructions in the channel other than the piling, and the current is never sluggish, even at low water. No attempt has ever been made to obtain records of winter flow, as the river often freezes solid. The range of gage heights is about 3 feet.

Discharge measurements are made from the upstream side of the highway bridge, which consists of 187 spans of 20 feet each, supported on piles.

On account of the extreme width (3,720 feet between banks) and shallowness of the stream, and also to partly eliminate the effect of the wind, two gages are maintained at this station. Both are of the standard chain and weight type and their zeros have the same elevation. One is located at the north end of the downstream side of the bridge and the other at the south end of the upstream side. The wind sometimes creates a difference of more than a foot between the two gages, but this difficulty is in part obviated by using the mean of the two readings in the computations of the daily discharge. The gages are referred to bench marks as follows: (1) The top of the east end of the first cap at the north end of the bridge; elevation, 7.66 feet above the zero of the gage and 2,392 feet above sea level. (2) The top of the upstream end of the cap of the third bent from the north end of the bridge, marked with a cross; elevation, 9.22 feet above the zero of the gage. (3) The top of the upstream end of the cap of the third bent from the south end of the bridge, marked with a cross; elevation, 9.03 feet above the zero of the gage.

Discharge measurements of Platte River near Lexington, 1902–1906.

Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Sec.-ft.*
April 8	B. E. Forbes		2,293
May 2	H. O. Smith	2.85	2,693
May 22	do	3.37	7,764
June 3	do	3.00	3,037
June 18	do	3.25	6,555
July 5	do	2.98	4,993
July 19	do	2.30	1,002
July 29	do	2.25	185
August 22	do	2.00	
August 23	do	1.20	
September 25	do	2.85	2,829
November 8	do	2.70	1,127
1903.			
May 8	J. C. Stevens	3.35	7,437
June 12	do	3.36	4,749
June 28	do	3.62	9,645
July 9	do	3.25	5,188
July 23	do	2.77	2,075
August 15	do	2.88	1,340
September 30	do	2.52	250
September 22	W. C. Sturdevant	2.60	296
November 1	J. C. Stevens	2.80	1,218
1904.		*Feet.*	*Sec.-ft.*
March	J. C. Stevens	3.34	3,070
May 14	do	3.54	4,731
May 27	do	4.10	10,606
June 14	do	4.48	19,100
July 27	do	3.32	1,690
September 1	do	2.99	125
1905.			
April 11	G. W. Bates	3.50	2,473
May 16	do	4.25	13,820
June 12	H. C. Gardner	4.93	25,830
July 10	do	3.93	11,010
July 18	do	3.38	2,882
August 2	do	3.48	2,877
August 23	H. O. Smith		0
September 6	H. C. Gardner	3.25	990
September 20	F. S. Dobson	3.10	760
1906.			
April 10	do	3.83	6,568
May 10	do	3.93	6,558
July 8	Arthur Dobson	3.83	4,913
July 31	do	3.52	2,038
September 8	A. R. Wilson	3.38	780
October 19	Arthur Dobson	3.40	1,541
November 10	do	3.78	4,925

SANDY BED OF PLATTE RIVER.

Mean daily gage height, in feet, of Platte River near Lexington, 1902–1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1					2.95	3.25	.....	2.35	1.70	2.45	2.70	2.80
2					2.85	2.95	.....	2.00	1.60	2.55	2.60	2.70
3					2.80	2.90	.....	1.95	1.50	2.55	2.65	2.30
4					2.75	3.00	.....	1.80	1.45	2.50	2.45	2.35
5					2.85	2.90	3.00	1.80	1.40	2.50	2.60	2.25
6					2.80	2.90	3.00	1.70	1.40	2.40	2.60	2.25
7					2.90	2.55	2.90	1.65	1.35	2.45	2.75	2.25
8					2.90	2.75	3.05	1.60	1.30	2.55	2.70	2.15
9					2.70	3.15	2.70	1.85	1.20	2.50	.....	2.25
10					2.75	.....	3.00	1.65	1.15	2.45	.....	2.30
11					2.75	3.00	2.90	1.60	1.10	2.70	.....	2.30
12					2.75	3.05	3.00	1.50	1.10	2.75	.....	2.35
13					2.90	3.40	3.05	1.45	1.10	2.75	.....	2.30
14					3.10	3.35	2.65	1.40	1.05	2.70	.....	2.45
15				2.70	3.40	3.15	2.80	1.40	1.00	2.65	.....	2.50
16				2.65	3.40	3.30	2.50	1.35	1.00	2.65	.....	2.40
17				2.65	3.95	3.00	2.50	1.30	1.00	2.60	.....	2.50
18				2.60	3.70	3.25	2.35	1.30	0.95	2.65	.....	2.50
19				2.70	3.60	3.25	2.30	1.25	0.95	2.65	.....	2.60
20				2.75	3.40	3.25	2.25	1.20	0.90	2.80	.....	2.70
21				2.70	3.20	3.10	2.25	1.20	1.60	2.70	.....	2.65
22				2.60	3.35	3.35	2.15	1.20	2.10	2.60	.....	2.60
23				2.60	3.40	3.20	2.10	1.25	2.05	2.60	.....	2.70
24				2.75	3.30	3.40	2.05	1.30	2.25	2.60	.....	2.70
25				2.65	3.20	3.40	2.00	1.40	2.85	2.60	.....	2.80
26				2.60	3.20	3.10	2.40	1.45	2.35	2.60	.....	2.70
27				2.90	3.25	3.10	2.40	1.35	2.70	2.65	.....	2.80
28				2.70	3.30	.....	2.35	1.30	2.70	2.80	.....	2.85
29				2.75	3.40	.....	2.15	1.25	2.40	2.65	.....	2.85
30				2.80	3.35	.....	2.40	2.15	2.45	2.70	.....	3.00
31				.....	3.30	.....	2.30	2.00	.....	2.70	.....	3.00
1903.												
1	3.05	3.80	4.00	2.90	3.35	3.20	3.45	2.95	2.80	2.55	2.85	2.45
2	3.00	3.80	4.00	2.75	2.80	3.20	3.55	2.85	2.90	2.70	2.80	2.35
3	3.15	3.75	4.00	2.70	3.35	3.20	3.55	2.90	2.80	2.75	2.85	3.20
4	3.20	3.65	4.05	3.00	3.05	3.25	3.40	2.80	2.65	2.75	2.80	2.85
5	3.20	3.75	4.05	2.90	3.10	3.20	3.50	2.65	2.50	2.80	2.75	3.00
6	3.25	3.75	4.05	2.75	3.05	3.15	3.40	2.60	2.45	2.85	2.90	2.95
7	3.15	3.70	4.10	2.75	3.35	3.10	3.35	2.55	2.50	2.75	2.95	3.00
8	3.25	3.65	4.15	2.75	3.35	3.10	3.25	2.60	2.40	2.75	3.00	2.95
9	3.35	3.65	4.30	2.80	3.35	3.10	3.10	2.60	2.50	2.75	2.75	3.00
10	3.35	3.65	4.55	2.90	3.10	3.00	2.90	2.55	2.40	2.90	2.85	3.00
11	3.40	3.70	4.65	3.00	3.05	3.15	2.90	2.70	2.55	2.80	2.90	3.10
12	3.40	3.75	4.65	2.70	2.75	3.35	3.00	2.75	2.50	2.70	2.85	3.15
13	3.50	3.75	4.75	2.75	3.05	3.25	3.00	2.80	2.35	2.60	2.90	.....
14	3.50	3.80	3.80	2.90	3.15	3.20	3.05	2.85	2.40	2.60	2.85	.....
15	3.45	3.80	4.90	2.90	3.10	3.30	3.10	2.90	2.40	2.75	2.80	.....
16	3.50	3.80	4.80	2.90	3.10	3.25	3.00	2.95	2.45	2.75	2.75	.....
17	3.50	3.80	4.20	3.00	3.35	3.50	3.05	2.90	2.45	2.75	2.55	.....
18	3.55	3.85	4.50	3.05	3.15	3.40	2.90	2.85	2.50	2.85	2.50	.....
19	3.60	3.80	4.10	2.80	3.15	3.45	2.85	2.80	2.55	2.80	2.60	.....
20	3.60	3.80	3.50	2.85	3.00	3.55	2.95	2.80	2.55	2.80	2.55	.....
21	3.65	3.80	3.65	2.95	3.40	3.65	2.85	2.75	2.60	2.70	2.50	.....
22	3.65	3.80	3.50	2.95	3.35	3.60	2.85	2.70	2.60	2.75	2.50	.....
23	3.70	3.85	3.10	3.05	3.15	3.65	2.80	2.60	2.55	2.80	2.70	.....
24	3.65	3.85	3.15	2.95	3.10	3.85	2.80	2.55	2.55	2.80	2.75	.....
25	3.65	3.90	3.00	2.90	3.05	3.80	2.75	2.50	2.50	2.75	2.60	.....
26	3.60	3.95	3.00	3.40	3.25	3.80	2.75	2.70	2.35	2.80	2.65	.....
27	3.65	3.90	3.40	3.40	3.30	3.85	2.95	2.70	2.30	2.75	2.70	.....
28	3.70	3.95	3.20	2.70	3.40	3.65	2.70	2.60	2.40	2.80	3.05	.....
29	3.75	.....	3.35	3.10	2.80	3.55	2.80	2.65	2.55	2.95	2.90	.....
30	3.75	.....	3.10	3.50	3.15	3.65	2.85	2.70	2.60	2.85	2.60	.....
31	3.70	.....	3.00	.....	3.15	.....	2.90	2.75	.....	2.80	.....	.....
1904.												
1				3.14	.....	4.00	3.85	3.19	3.00	3.22	3.35	.....
2				3.28	3.14	4.12	3.78	3.18	3.05	.....	3.36	.....
3				.....	3.20	4.15	.....	3.25	3.02	3.32	3.34	.....
4				3.22	3.58	4.20	.....	3.20	.....	3.28	3.32	.....
5				3.20	3.70	.....	3.88	3.29	3.05	3.10	3.38	.....

Mean daily gage height, in feet, of Platte River near Lexington, 1902–1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.												
6				3.29	3.60	4.11	3.78	3.18	3.02	3.18		
7				3.32	3.56	4.05	3.88		3.02	3.22	3.30	
8						4.00	3.85	3.32	2.98	3.10	3.30	
9				3.05	3.45	4.02	3.72	3.22	2.92		3.35	
10					3.65	4.28		3.20	2.90	3.12	3.48	
11				3.25	3.70	4.32	3.60	3.15		3.12	3.25	
12				3.10	3.68		3.65	3.08	2.92	3.15	3.28	
13				3.10	3.52	4.50	3.60	3.00	3.18	3.18		
14				2.98	3.55	4.42	3.55		3.00	3.20	3.38	
15				3.19		4.42	3.55	2.92	2.82	3.20	3.40	
16				3.10		4.35	3.50	2.90	2.80		3.35	
17					3.50	4.48		2.82	2.75	3.12	3.32	
18				3.06	3.55	4.25	3.40	3.22		3.30	3.35	
19				3.02	3.55		3.35	3.10	2.70	3.40	3.40	
20				3.08	3.52	4.24	3.40	2.92		3.35		
21				3.06	3.45	4.20	3.40	2.88		3.38	3.35	
22				3.14		4.22	3.38	2.68		3.35	3.35	
23				3.15	3.38	4.10	3.42	2.58			3.35	
24					3.50	4.16			2.85	3.35		
25				2.98	3.40	4.18	3.32			3.28	3.42	
26				2.98	3.55		3.32		2.80	3.28	3.42	
27				3.08	4.10	4.10	3.32		2.75	3.35		
28			3.32	3.20	3.88	4.00	3.32		3.15	3.30	3.45	
29			3.22	3.12		3.98	3.28	3.25	3.10	3.28	3.38	
30			3.15	3.12	3.84	3.92	3.20	3.12	3.15		3.38	
31			3.18		3.92			3.10		3.32		
1905.												
1				3.45	4.2	4.9	4.05	3.6	3.15	3.15		
2				3.52	4.2	4.9	4.25	3.48	3.2	3.18		
3				3.58	4.28	4.9	4.48	3.6	3.2	3.15		
4				3.62	4.3	4.85	4.33	3.55	3.2	3.15		
5				3.62	4.32	4.8	4.18	3.48	3.35	3.15		
6				3.62	4.32	4.65	4.05	3.45	3.25	3.15		
7				3.6	4.36	4.55	4.2	3.42	3.22	3.15		
8				3.55	4.4	4.5	4.08	3.42	3.2	3.16		
9				3.48	4.35	4.5	4.0	3.45	3.2	3.18		
10				3.4	4.35	4.75	3.92	3.5	3.16	3.12		
11				3.45	4.42	4.82	3.92	3.35	3.12	3.1		
12				3.42	4.52	4.9	3.85	3.3	3.12	3.18		
13				3.52	4.52	4.8	3.82	3.3	3.15	3.15		
14				3.5	4.44	4.72	3.75	3.32	3.12	3.25		
15				3.5	4.35	5.0	3.65	3.38	3.12	3.26		
16				3.5	4.25	5.15	3.6	3.42	3.28	3.28		
17				3.52	4.28	5.05	3.55	3.45	3.33	3.3		
18				3.55	4.25	4.95	3.42	3.3	3.38	3.3		
19				3.52	4.22	4.82	3.40	3.28	3.32	3.32		
20				3.52	4.3	4.78	3.42	3.28	3.28	3.28		
21				3.72	4.3	4.68	3.4	3.28	3.28	3.28		
22				3.82	4.3	4.58	3.62	3.42	3.3	3.3		
23				3.85	4.2	4.75	3.56	3.4	3.3	3.3		
24			3.55	3.88	4.15	4.7	3.5	3.28	3.25	3.3		
25			3.42	4.05	4.12	4.55	3.42	3.25	3.2	3.3		
26			3.45	4.12	4.25	4.42	3.42	3.25	3.2	3.32		
27			3.45	4.15	4.3	4.32	3.4	3.22	3.18	3.3		
28			3.38	4.15		4.2	3.32	3.18	3.15	3.32		
29			3.42	4.12	4.75	4.12	3.38	3.2	3.1	3.35		
30			3.50	4.16	4.72	4.1	3.42	3.18	3.12	3.38		
31			3.50		4.78		3.45	3.18		3.4		
1906.												
1					3.97	4.27	3.85	3.45	3.30	3.37	3.81	
2					3.97	4.42	3.72	3.40	3.35	3.35	3.92	
3					4.00	4.44	3.80	3.45	3.35	3.35	3.92	
4					4.00	4.47	3.81	3.57	3.40	3.45	3.94	
5				3.82	3.95	4.47	3.82	3.61	3.40	3.40	3.95	
6				3.82	3.98	4.50	3.87	3.65	3.40	3.42	3.90	
7				3.77	4.02	4.50	3.80	3.60	3.35	3.44	3.77	
8				3.80	3.97	4.42	3.83	3.50	3.37	3.45	3.80	
9				3.82	3.92	4.17	3.72	3.47	3.33	3.45	3.80	
10				3.87	3.95	4.11	3.67	3.40	3.30	3.42	3.81	

Mean daily gage height, in feet, of Platte River near Lexington, 1902–1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906.												
11				3.95	3.95	4.05	3.57	3.40	3.25	3.42	3.86	
12				3.87	3.85	3.97	3.60	3.34	3.42	3.42	3.90	
13				3.80	3.82	3.95	3.60	3.27	3.45	3.45	3.85	
14				3.82	3.80	4.00	3.55	3.22	3.52	3.46	3.80	
15				3.87	3.82	4.05	3.56	3.20	3.50	3.47	3.80	
16				3.92	3.85	4.02	3.59	3.17	3.44	3.37	3.66	
17				3.85	3.75	3.97	3.55	3.20	3.37	3.50	3.80	
18				3.80	3.77	3.92	3.55	3.20	3.37	3.45	3.75	
19				3.80	3.72	3.87	3.55	3.15	3.40	3.50	3.70	
20				3.80	3.80	3.90	3.60	3.10	3.42	3.52	3.60	
21				3.85	3.87	3.85	3.62	3.07	3.45	3.52	3.60	
22				3.84	4.00	4.05	3.60	3.02	3.47	3.52	3.48	
23				3.82	4.00	4.07	3.57	3.00	3.46	3.57	3.32	
24				3.75	4.02	4.10	3.55	3.10	3.45	3.55	3.32	
25				3.72	4.07	4.12	3.55	3.25	3.40	3.52	3.46	
26				3.70	4.20	4.15	3.65	3.30	3.42	3.55	3.60	
27				3.80	4.16	4.10	3.60	3.35	3.40	3.55	3.65	
28				3.87	4.12	4.07	3.55	3.42	3.42	3.75	3.60	
29				3.95	4.55	4.02	3.52	3.27	3.40	3.95	3.42	
30				3.96	4.15	3.97	3.50	3.27	3.38	3.77	3.25	
31					4.20		3.52	3.25		3.90		

Mean daily discharge, in second-feet, of Platte River near Lexington, 1902–1906.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.									
1			3,895	5,232		565	0	836	1,226
2			2,693	2,760		0	0	1,158	892
3			2,400	2,400		0	0	1,124	1,022
4			2,112	3,092		0	0	954	465
5			2,760	3,160	5,140	0	0	920	836
6			2,460	2,580	5,140	0	0	640	836
7			3,092	2,340	4,290	0	0	780	1,302
8		2,293	3,160	1,842	5,600	0	0	1,056	1,106
9			1,950	3,432	2,820	0	0	892	
10			2,220		5,140	0	0	724	
11			2,280	3,500	4,373	0	0	1,596	
12			2,280	3,816	5,232	0	0	1,842	
13			3,228	7,204	5,692	0	0	1,788	
14			4,885	6,906	2,580	0	0	1,554	
15		2,220	7,714	5,232	3,579	0	0	1,302	
16		1,950	7,714	6,812	1,788	0	0	1,302	
17		1,950	14,672	4,211	1,788	0	0	1,056	
18		1,680	11,264	6,555	1,158	0	0	1,260	
19		2,220	10,004	6,624	1,002	0	0	1,200	
20		2,520	7,918	6,718	780	0	0	1,896	
21		2,220	5,968	5,416	696	0	0	1,428	
22		1,680	7,408	7,918	367	0	0	1,055	
23		1,680	7,918	6,530	160	0	0	1,022	
24		2,520	6,812	8,644	32	0	367	1,022	
25		1,950	5,784	8,748	0	0	2,780	988	
26		1,680	5,692	5,876	696	0	615	988	
27		3,500	5,968	5,968	640	0	1,896	1,124	
28		2,220	6,342		465	0	1,842	1,734	
29		2,520	7,204		184	0	724	1,090	
30		2,820	6,530		590	275	836	1,260	
31			5,876		390	0		1,260	
1903.									
1		3,500	7,510	4,715	8,020	2,220	920	390	1,470
2		2,520	2,820	4,715	9,060	1,680	1,260	780	1,260
3		2,220	7,510	4,290	8,540	1,950	920	920	1,470
4		4,290	4,715	4,715	7,000	1,470	515	1,920	1,260
5		3,500	5,140	4,290	8,020	920	160	1,260	1,090

Mean daily discharge, in second-feet, of Platte River near Lexington, 1902–1906—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1903.									
6	.....	2,520	4,715	3,500	7,000	640	80	1,470	1,680
7	.....	2,520	7,510	3,160	6,530	515	160	1,090	1,950
8	.....	2,520	7,510	3,160	5,600	640	0	1,090	2,220
9	.....	2,820	7,510	3,160	3,895	640	160	1,090	1,090
10	.....	3,500	5,140	2,520	2,520	515	0	1,680	1,470
11	.....	4,290	4,715	3,500	2,520	920	275	1,260	1,680
12	.....	2,220	2,520	4,715	3,160	1,090	160	920	1,470
13	.....	2,520	4,715	3,895	3,160	1,260	0	640	1,680
14	.....	3,500	5,140	3,500	3,500	1,470	0	640	1,470
15	.....	3,500	4,715	4,290	3,895	1,470	0	1,090	1,260
16	.....	3,500	4,715	4,290	3,160	1,680	80	1,090	1,470
17	.....	4,290	7,000	6,530	3,500	1,470	0	1,090	.....
18	.....	4,715	5,140	5,600	2,520	1,260	80	1,470	.....
19	.....	2,820	4,715	6,530	1,950	1,090	160	1,260	.....
20	9,060	3,160	3,500	7,510	2,520	1,090	160	1,260	.....
21	10,880	3,895	7,000	8,540	1,950	920	275	920	.....
22	9,060	3,895	6,530	9,060	1,950	780	275	1,090	.....
23	5,140	4,715	4,715	9,650	1,680	515	160	1,260	.....
24	5,600	3,895	4,290	12,190	1,680	390	160	1,260	.....
25	4,290	3,500	3,895	11,520	1,470	275	160	1,090	.....
26	4,290	8,020	5,140	12,190	1,470	780	80	1,260	.....
27	8,020	8,020	5,600	12,860	2,520	780	0	1,090	.....
28	6,060	2,220	6,530	10,240	1,090	515	80	1,260	.....
29	7,510	5,140	1,950	9,060	1,470	640	390	1,950	.....
30	5,140	9,060	4,290	10,240	1,680	780	515	1,470	.....
31	4,290	.....	4,290	.....	1,950	920	.....	1,260	.....
1904.									
1	.....	1,050	1,025	9,100	7,100	1,350	200	1,350	2,350
2	.....	2,000	1,050	10,600	6,500	1,350	475	1,575	2,350
3	.....	1,675	1,350	11,600	6,900	1,675	200	2,000	2,350
4	.....	1,350	4,400	12,600	7,300	1,350	330	2,000	2,000
5	.....	1,350	5,400	11,600	7,700	2,000	475	750	2,700
6	.....	2,000	4,400	10,600	6,500	1,350	200	2,000	2,350
7	.....	2,000	3,950	9,850	7,700	1,675	200	1,350	2,000
8	.....	1,350	3,525	9,100	7,100	2,000	200	750	2,000
9	.....	1,000	3,100	9,100	5,400	1,350	100	750	2,350
10	.....	1,350	4,900	14,700	4,900	1,350	100	750	1,600
11	.....	1,675	5,400	14,700	4,400	1,050	100	750	1,675
12	.....	1,000	5,400	15,050	4,900	750	100	1,050	2,000
13	.....	1,000	3,500	19,400	4,400	200	1,350	1,350	2,350
14	.....	1,000	3,950	16,900	3,950	150	200	1,350	2,700
15	.....	1,350	3,800	16,900	3,950	100	100	1,350	2,700
16	.....	1,000	3,650	15,800	3,500	100	100	1,050	2,350
17	.....	1,100	3,500	19,400	3,100	100	100	750	2,000
18	.....	1,000	3,950	13,650	2,700	1,350	100	2,000	2,350
19	.....	1,000	3,950	13,650	2,300	750	100	2,700	2,700
20	.....	1,000	3,500	13,650	2,700	100	0	2,350	2,525
21	.....	1,000	3,100	12,600	2,700	100	0	2,700	2,350
22	.....	1,050	2,900	12,600	2,700	100	0	2,350	2,350
23	.....	1,050	2,700	10,600	2,700	100	0	2,350	2,350
24	.....	1,025	3,500	11,600	2,350	0	100	2,350	2,525
25	.....	1,000	2,700	12,600	2,000	0	100	2,000	2,700
26	.....	1,000	3,950	11,600	2,000	0	100	2,000	2,700
27	.....	1,000	10,600	10,600	2,000	0	100	2,350	.....
28	2,000	1,350	7,700	9,100	2,000	0	1,050	2,000	.....
29	1,350	1,000	7,400	9,100	2,000	1,675	750	2,000	.....
30	1,350	1,000	7,100	7,700	1,350	750	1,050	2,000	.....
31	1,350	.....	7,700	.....	1,350	750	.....	2,000	.....
1905.									
1	.....	2,150	12,500	27,600	11,500	3,900	0	.....	.....
2	.....	2,600	12,500	27,600	15,600	2,900	300	.....	.....
3	.....	3,100	14,200	26,400	21,600	3,800	300	.....	.....
4	.....	3,400	14,700	25,200	17,800	3,400	300	.....	.....
5	.....	3,400	15,100	24,000	14,200	2,900	1,200	.....	.....
6	.....	3,400	15,100	20,300	11,600	2,200	990	.....	.....
7	.....	3,600	16,000	17,700	16,700	1,900	800	.....	.....
8	.....	3,250	17,000	16,500	14,000	1,900	800	.....	.....
9	.....	2,700	15,800	16,500	12,300	2,200	800	.....	.....
10	.....	2,100	16,100	21,400	11,000	2,500	600	.....	.....

Mean daily discharge, in second-feet, of Platte River near Lexington, 1902–1906—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1905.									
11		2,500	18,000	23,200	11,000	900	400		
12		2,300	20,300	25,200	9,600	700	500		
13		3,000	20,300	22,600	8,000	700	700		
14		2,850	18,400	20,700	7,200	800	500		
15		2,850	16,200	27,700	6,000	1,100	700		
16		2,850	13,800	30,000	5,500	600	1,600		
17		3,400	14,600	29,000	4,300	800	200		
18		3,650	13,800	28,000	3,200	100	2,300		
19		3,400	13,300	25,500	3,000	100	2,100		
20		3,400	14,000	24,300	3,200	100	1,900		
21		5,200	14,000	22,000	3,000	100	1,900		
22		6,300	14,000	19,400	4,700	100	2,000		
23		6,600	12,000	26,100	4,100	0	2,000		
24	2,900	7,000	11,100	25,000	3,600	0	1,700		
25	1,900	9,300	10,500	21,100	3,000	0	1,300		
26	2,000	10,400	13,000	17,900	2,800	0	1,300		
27	2,150	10,900	13,000	15,600	2,650	0	1,200		
28	1,650	11,500	18,200	12,900	2,100	0	1,000		
29	1,900	11,000	23,700	11,800	2,300	0	800		
30	2,470	11,700	23,100	12,600	2,600	0	900		
31	2,470		24,500		2,800	0			
1906.									
1			8,100	12,500	5,100	1,400	200	1,000	5,600
2			8,100	15,500	3,600	1,000	600	900	7,100
3			8,500	15,800	4,500	1,400	600	900	7,000
4			8,500	16,400	4,600	2,400	900	1,600	7,200
5		6,500	7,700	16,400	4,700	2,800	900	1,200	7,400
6		6,500	8,200	17,000	5,400	3,000	900	1,600	6,700
7		5,800	8,800	17,000	4,500	2,700	600	1,700	5,000
8		6,100	7,500	15,400	4,900	1,800	700	1,800	5,200
9		6,500	6,800	10,500	3,600	1,600	500	1,800	5,200
10		7,200	7,200	9,400	3,100	1,000	250	1,600	5,300
11		8,500	7,200	8,400	2,100	1,000	100	1,600	6,000
12		7,100	5,800	7,100	2,600	600	1,100	1,600	6,500
13		6,200	5,400	6,800	2,600	100	1,300	1,800	5,800
14		6,400	5,200	7,500	2,100	0	1,900	1,900	5,200
15		6,800	5,400	8,400	2,200	0	1,800	2,000	5,200
16		7,600	5,800	7,900	2,300	0	1,400	1,300	3,600
17		6,600	4,500	7,000	2,100	0	900	2,400	5,200
18		6,000	4,800	6,300	2,200	0	900	2,000	4,600
19		6,000	4,000	5,500	2,200	0	1,100	2,400	4,000
20		6,000	4,900	6,000	2,600	0	1,300	2,700	2,900
21		6,600	5,900	5,300	2,800	0	1,500	2,700	2,900
22		6,500	7,700	8,100	2,600	0	1,700	2,700	1,800
23		6,100	7,700	8,500	2,400	0	1,600	2,900	600
24		5,000	8,000	9,000	2,200	0	1,500	2,700	600
25		4,600	8,900	9,300	2,200	100	1,100	2,400	1,700
26		4,400	11,100	9,900	3,200	200	1,400	2,700	3,000
27		5,600	10,400	9,000	2,700	600	1,200	2,700	3,400
28		6,600	9,700	8,500	2,300	1,100	1,400	4,800	3,000
29		7,700	18,000	7,800	2,000	100	1,200	7,600	1,300
30		8,000	10,200	7,000	1,900	100	1,100	5,000	200
31			11,000		2,000	100		6,800	

Estimated monthly discharge of Platte River near Lexington, 1902–1906.

[Drainage area, 53,300 square miles.]

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
March.								
1903 [a]	10,880	4,290	6,612	157,400	.....	.....	.....	0.85
1904 [b]	2,000	1,350	1,512	12,000	.....	.....	.....	.77
1905 [c]	2,900	1,650	2,180	34,600	.....	.....	.....	.77
April.								
1902 [d]	3,500	1,680	2,208	70,000	.....	.....	.....	1.08
1903	9,060	2,220	3,893	231,600	0.073	0.08	6	1.25
1904	2,000	1,000	1,218	72,500	.023	.03	3	1.08
1905	11,700	2,100	4,990	297,000	.094	.10	3	3.45
1906	8,500	4,400	6,420	382,000	.120	.13	7	1.93
May.								
1902	14,670	1,950	5,490	337,500	.103	.12	5	2.64
1903	7,510	1,950	3,749	230,500	.070	.08	4	1.91
1904	10,700	1,020	4,295	264,100	.081	.09	2	3.67
1905	24,500	10,500	15,800	972,000	.296	.34	10	3.43
1906	18,000	4,000	7,770	478,000	.146	.17	6	2.63
June.								
1902	8,750	1,840	5,135	305,500	.096	.13	6	2.17
1903	12,860	2,520	6,471	385,000	.121	.13	7	1.99
1904	19,500	7,700	12,570	748,000	.236	.26	8	3.16
1905	30,000	11,800	22,100	1,320,000	.415	.46	21	2.11
1906	17,000	5,300	9,970	593,000	.187	.21	17	1.71
July.								
1902	5,690	0	2,234	137,400	.042	.05	2	2.02
1903	9,060	1,090	3,709	228,000	.070	.08	3	2.51
1904	7,700	1,350	4,071	250,300	.076	.09	4	2.51
1905	21,600	2,100	7,770	478,000	.146	.17	6	2.67
1906	5,400	1,900	3,010	185,000	.056	.06	4	1.46
August.								
1902	565	0	27	1,700	.001	.001	.8	1.22
1903	2,220	275	1,009	62,000	.042	.02	1	2.01
1904	2,000	0	760	46,700	.014	.02	1	1.60
1905	3,900	0	1,090	67,000	.020	.02	2	1.25
1906	3,000	0	745	45,800	.014	.02	1	2.04
September.								
1902	2,780	0	302	18,000	.006	.01	.3	2.93
1903	1,260	0	237	14,100	.004	.004	.3	1.24
1904	1,350	0	266	15,800	.005	.01	1	1.49
1905	2,300	0	1,040	61,800	.020	.02	2	1.32
1906	1,900	100	1,060	63,100	.020	.02	1	1.98
October.								
1902	1,900	640	1,191	73,200	.022	.02	2	1.08
1903	1,950	390	1,140	70,100	.021	.02	2	.79
1904	2,700	750	1,662	102,200	.031	.04	4	1.09
1906	7,600	900	2,482	152,000	.047	.05	3	2.07
November.								
1902 [a]	1,230	465	961	15,300	.....	.....	.....	.37
1903 [b]	2,220	1,090	1,499	47,600	.....	.....	.....	.33
1904 [c]	3,100	1,600	2,392	142,300	.....	.....	.....	.04
1906	7,400	200	4,210	251,000	.079	.09	10	.87

[a] March 20 to 31. [b] March 28 to 31. [c] March 24 to 31. [d] April 15 to 30.

PLATTE RIVER NEAR COLUMBUS.

The station near Columbus was established June 4, 1895, and has been maintained continuously since that date except during the winter months. It is located above the mouth of Loup River at the Meridian bridge, about 3 miles south of Columbus, in sec. 31,

T. 17 N., R. 1 E., and is shown on the David City atlas sheet of the United States Geological Survey.

The stream flows in three channels, known as the main, middle, and south channels, having widths of 194, 320, and 75 feet, respectively. At the gaging section the main and middle channels are straight. The bed is of shifting sand, and the banks are low but not subject to overflow. In the south channel the stream flows at an angle of about 25° to the bridge. A small tributary furnishes a supply of water in the south channel even when the other channels are entirely dry. The only obstructions to flow are the bridge piles. The current is never sluggish, even at extreme low stages. Gage heights have a range of about 6 feet.

Discharge measurements are made from pile bridges which cross the three channels. The Meridian bridge lies on the sixth principal meridian, and consists of sixty-five 30-foot spans across the main channel.

The gage is of the standard weight and chain type and is fastened to the downstream hand rail of the bridge approach near the left bank of the main channel. The length of the chain from index to end of weight is 16.21 feet. The gage is referred to a standard United States Geological Survey bench mark, 60 feet north of the north end of the bridge truss and 10 feet west of a large cottonwood tree; elevation, 7.06 feet above the zero of the gage.

In past years deposits of sand about the gage have made it impossible to obtain uninterrupted records, even during the open season.

Discharge measurements of Platte River near Columbus, 1896–1906.

Date.	Hydrographer.	Gage height.	Discharge.
1896.		*Feet.*	*Sec.-ft.*
June 5	O. V. P. Stout	3.19	4,320
June 14	do	4.11	10,307
June 30	do	3.35	4,450
July 22	E. T. Youngfelt		14
August 26	O. V. P. Stout	1.06	1
August 28	E. T. Youngfelt		0
September 6	O. V. P. Stout		0
September 25	E. T. Youngfelt	1.70	188
1897.			
March 20	Adna Dobson	2.90	4,963
April 29	do	3.93	8,608
May 5	do	3.79	7,322
May 26	do	4.31	10,694
June 17	O. V. P. Stout	4.37	12,685
July 11	do	3.05	4,001
July 28	do	2.43	994
August 17	do	3.18	3,343
August 29	do	2.50	1,649
October 7	Adna Dobson		2
November 20	do	2.88	2,645
1898.			
April 17	Glenn E. Smith	2.37	1,994
May 9	do	3.65	5,612
May 19	do	3.33	3,619
May 29	do	3.82	7,104
June 8	do	4.69	16,543
June 19	O. V. P. Stout	3.95	9,123
July 10	Glenn E. Smith	3.00	3,006
July 29	do		285
July 31	do		45
August 21	Adna Dobson		2
September 4	do		2
September 18	do		10
October 16	do		14
October 30	do		13
November 11	Glenn E. Smith		16
November 20	do		25
1899.			
April 9	do	3.50	6,736
April 23	do	3.94	8,210
May 7	do	4.14	10,121
May 23	do	3.81	7,878
June 4	do	4.01	9,294
June 18	do	4.00	9,279
June 29	do	4.82	18,631
July 9	do	4.61	17,032
July 23	do	3.84	8,693
August 6	do	4.00	9,450
August 20	do	2.80	3,338
September 3	do	.90	93
September 17	do		15
October 5	do		0
October 15	do		8

Discharge measurements of Platte River near Columbus, 1896–1906—Continued.

Date.	Hydrographer.	Gage height.	Discharge.
1900.		*Feet.*	*Sec.-ft.*
April 8	Adna Dobson	2.68	1,907
April 29	do	4.58	15,673
May 13	do	5.05	21,826
May 27	do	4.00	18,557
June 10	do	4.95	15,696
June 24	do	4.30	12,519
July 15	do	2.06	1,456
July 29	do	.98	394
August 26	do	.86	149
September 16	do	1.07	403
October 31	do	1.72	998
November 30	do	1.17	317
December 19	do	1.33	569
1901.			
March 31	do	2.50	1,816
April 21	do	3.25	4,824
May 10	do	3.45	6,799
June 7	B. E. Forbes	3.90	8,241
June 18	do	4.35	11,949
July 14	O. V. P. Stout	.....	379
August 11	do	.....	20
October 6	F. Dobson	.....	20
November 2	do	1.90	978
December 1	do	1.85	922
1902.			
March 8	do	3.39	5,664
April 13	do	2.22	996
May 11	do	2.37	1,695
May 22	J. C. Stevens	2.75	8,447
June 1	do	3.38	5,852
July 11	do	3.55	6,992
August 10	do	1.31	350
August 26	do	1.60	546
September 11	do	.50	5
October 5	do	2.50	1,989
1903.			
April 3	J. C. Stevens	3.28	5,912
May 7	do	3.54	5,420
June 11	do	3.55	4,934
June 27	do	4.64	13,133
July 10	do	3.96	7,198
July 17	do	4.10	7,524
August 1	do	3.87	5,864
August 18	do	3.62	2,898
September 29	do	2.00	126
October 31	do	2.82	878
1904.			
May 8	do	3.85	5,747
June 18	do	4.52	15,194
June 25	do	4.13	12,024
July 28	do	2.96	2,549
September 2	O. H. Timmerman	1.91	60
1905.			
March 16	Adna Dobson	3.08	3,978
April 27	H. C. Gardner	4.45	13,630
May 16	do	5.60	33,410
June 21	do	5.10	27,570
July 8	do	4.45	19,760
July 14	do	3.50	8,514
August 12	do	2.25	2,341
September 27	F. S. Dobson	2.10	1,739
October 13	do	1.80	891
1906.			
April 30	Geo. W. Bates	4.51	16,814
May 3	do	5.12	19,770
June 8	Arthur Dobson	4.52	13,795
July 13	do	2.90	2,877
August 28	do	1.24	51
September 29	do	1.88	594
October 27	do	2.98	3,157
November 24	do	2.65	2,147

Mean daily gage height, in feet, of Platte River near Columbus, 1895–1906.

Day.	June.	July.	Aug.	Day.	June.	July.	Aug.	Day.	June.	July.	Aug.
1895.				1895.				1895.			
1	.....	1.12	0.20	12	2.05	0.62	0.14	23	1.50	0.35	0.19
2	.....	.98	.12	13	2.05	.61	.22	24	1.43	.33	.22
3	.....	.85	.01	14	1.90	.64	.17	25	1.45	.33	.15
4	.....	.81	.03	15	1.78	.68	.10	26	1.40	.29	.04
5	.....	.69	.07	16	1.74	.59	.09	27	1.25	.23	−.04
6	.....	.59	.08	17	1.76	.50	.08	28	1.35	.24	−.07
7	.....	.56	.04	18	1.70	.45	.08	29	1.35	.26	−.10
8	.....	.61	.07	19	1.75	.52	.09	30	1.31	.26	.11
9	1.30	.54	.12	20	1.69	.48	.02	31	.....	.26	.17
10	1.43	.54	.06	21	1.62	.42	.02				
11	2.03	.49	.11	22	1.57	.39	.09				

Day.	June.	July.	Aug.	Oct.	Nov.	Dec.	Day.	June.	July.	Aug.	Oct.	Nov.	Dec.
1896.							1896.						
1	.....	3.30	.....	1.70	2.60	.....	17	4.10	1.00	1.35	1.80	2.65	.....
2	.....	3.30	1.90	1.70	2.60	.....	18	3.90	1.00	1.30	1.70	2.30	.....
3	.....	3.32	2.65	1.75	2.60	.....	19	3.86	.....	1.30	1.70	2.20	.....
4	3.40	3.32	2.45	1.70	2.68	.....	20	3.65	.....	1.20	1.70	2.20	2.80
5	3.24	3.28	2.20	1.75	2.70	2.60	21	3.60	.....	1.20	1.70	2.20	.....
6	3.50	3.10	2.15	1.80	2.70	.....	22	3.55	.....	1.30	1.70	2.20	.....
7	3.60	3.10	1.95	1.85	2.75	.....	23	3.69	.....	1.30	1.78	2.20	.....
8	3.78	3.04	1.80	1.90	2.80	6.45	24	3.60	.....	1.45	1.82	2.20	.....
9	4.04	2.94	1.78	1.95	3.05	.....	25	3.69	.....	1.70	1.90	2.30	.....
10	4.49	3.16	1.70	2.20	2.80	6.21	26	3.65	.....	1.50	1.90	2.40	.....
11	4.25	3.06	1.75	2.20	2.35	.....	27	3.70	.....	1.18	1.95	2.60	.....
12	4.28	2.69	1.80	2.10	1.90	6.58	28	3.59	.....	1.10	.....	2.60	3.01
13	4.15	2.50	1.90	2.10	1.90	2.60	29	3.48	.....	1.10	2.01	.....	.....
14	4.10	2.32	2.40	1.90	1.90	.....	30	3.32	.....	1.10	2.60	.....	.....
15	3.65	1.95	2.05	1.80	2.40	.....	31	.....	.....	1.10	2.70	.....	.....
16	3.90	1.70	1.70	1.80	2.90	.....							

Mean daily gage height, in feet, of Platte River near Columbus, 1895–1906—Continued.

Day.	May.	June.	July.	Aug.	Sept.	Oct.
1897.						
1	.....	4.90	3.90	(a)	(a)	(a)
2	.....	4.88	3.90	(a)	(a)	(a)
3	.....	4.88	3.82	(a)	(a)	(a)
4	3.70	5.15	3.65	(a)	(a)	(a)
5	3.75	4.95	3.35	(a)	(a)	(a)
6	3.82	4.80	3.18	(a)	(a)	(a)
7	3.95	4.80	3.10	(a)	(a)	(a)
8	4.10	4.85	3.10	(a)	(a)	(a)
9	4.05	4.90	3.10	(a)	(a)	(a)
10	4.20	4.95	3.00	(a)	(a)	(a)
11	4.15	5.00	2.85	(a)	(a)	(a)
12	4.20	5.20	2.70	(a)	(a)	(a)
13	4.20	5.20	2.70	(a)	(a)	(a)
14	4.20	4.82	2.70	(a)	(a)	(a)
15	4.30	4.68	2.70	(a)	(a)	(a)
16	4.30	4.58	2.70	(a)	(a)	(a)
17	4.30	4.42	2.70	2.70	(a)	(a)
18	4.40	4.05	2.70	2.80	(a)	(a)
19	4.40	3.90	(a)	2.80	(a)	(a)
20	4.28	3.95	(a)	2.90	(a)	(a)
21	4.20	4.20	(a)	2.90	(a)	(a)
22	4.20	4.32	(a)	2.90	(a)	(a)
23	4.10	4.22	(a)	2.80	(a)	(a)
24	4.00	4.18	(a)	2.70	(a)	(a)
25	4.15	4.25	(a)	2.60	(a)	(a)
26	4.30	4.30	(a)	2.60	(a)	(a)
27	4.28	4.30	(a)	2.60	(a)	2.20
28	4.48	4.25	(a)	2.60	(a)	2.20
29	4.52	4.15	(a)	2.20	(a)	2.25
30	4.75	3.95	(a)	2.20	(a)	2.25
31	4.90	(a)	(a)	2.20	(a)	(a)

Day.	Apr.	May.	June.	July.	Day.	Apr.	May.	June.	July.	Day.	Apr.	May.	June.	July.
1898.					1898.					1898.				
1	.....	2.50	3.90	3.60	12	.....	3.45	4.35	2.80	23	2.25	3.98	3.50	(a)
2	.....	2.80	5.10	3.40	13	.....	3.34	4.28	2.60	24	2.10	4.12	3.60	(a)
3	.....	3.22	4.50	3.42	14	.....	3.27	4.22	2.55	25	2.00	3.98	3.60	(a)
4	.....	3.40	5.00	3.45	15	.....	3.24	4.15	2.50	26	2.06	3.85	3.50	(a)
5	.....	3.70	4.90	3.40	16	.....	3.27	4.35	2.55	27	1.97	4.04	3.40	(a)
6	.....	3.75	4.72	3.38	17	2.36	3.34	4.20	2.50	28	1.95	3.93	3.42	(a)
7	.....	3.80	4.85	3.20	18	2.42	3.50	4.05	2.45	29	1.95	3.75	3.45	(a)
8	.....	3.70	4.65	3.15	19	2.55	3.28	3.96	2.20	30	2.60	3.85	3.50	(a)
9	.....	3.56	4.45	3.20	20	2.60	3.90	3.78	2.00	31	.....	4.03	.....	(a)
10	.....	3.55	4.52	3.00	21	2.65	4.30	3.56	(a)					
11	.....	3.35	4.48	2.90	22	2.40	4.10	3.58	(a)					

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Day.	Apr.	May.	June.	July.	Aug.	Sept.
1899.							1899.						
1	.....	3.90	4.30	5.10	3.70	1.20	17	3.10	3.41	4.98	4.40	2.95	.....
2	0.00	3.73	4.10	4.90	3.65	1.10	18	3.20	3.36	4.00	4.23	2.85	.....
3	.00	3.80	4.00	4.80	3.60	.90	19	3.60	3.21	4.00	4.11	2.81	.....
4	4.00	3.85	4.01	4.85	3.68	.85	20	3.80	3.30	4.00	4.10	2.80	.....
5	4.80	3.93	3.40	4.95	3.88	.80	21	4.00	3.91	4.20	4.00	2.81	.....
6	4.50	4.00	3.70	4.98	4.00	.70	22	3.90	4.10	4.40	3.90	2.80	.....
7	4.40	4.14	4.00	4.97	3.90	.65	23	3.94	3.81	4.50	3.83	2.75	.....
8	3.70	3.96	3.81	4.98	3.96	.60	24	3.50	4.50	4.63	3.80	2.70	.....
9	3.45	4.00	3.65	4.61	3.94	.50	25	3.93	4.70	4.40	3.70	2.60	.....
10	3.50	3.94	3.64	4.63	3.90	.....	26	4.50	4.90	4.43	3.72	2.55	.....
11	3.55	3.87	4.50	4.62	3.80	.....	27	3.90	5.05	4.50	3.74	2.40	.....
12	3.60	3.80	4.60	4.60	4.00	.....	28	3.83	4.83	4.75	3.80	2.00	.....
13	3.65	3.73	4.80	4.58	3.50	.....	29	3.90	4.70	4.85	3.90	1.60	.....
14	3.20	3.68	4.95	4.56	3.40	.....	30	3.93	4.60	5.15	3.92	1.50	.....
15	3.10	3.60	4.98	4.50	3.30	.....	31	.....	4.51	.....	3.85	1.35	.....
16	3.00	3.63	4.99	4.50	2.90	.....							

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1900.								
1	.....	4.00	4.45	3.30	0.10	(a)	(a)	1.60
2	.....	3.95	4.55	3.38	(a)	(a)	(a)	1.48
3	.....	3.94	4.69	3.32	(a)	(a)	(a)	1.37
4	.....	3.95	4.70	3.33	(a)	(a)	(a)	1.25
5	.....	4.65	4.66	3.87	(a)	(a)	(a)	1.23
6	.....	4.68	4.75	3.38	(a)	(a)	(a)	1.20
7	.....	5.60	5.05	2.95	(a)	(a)	(a)	1.16
8	2.69	5.30	5.00	2.87	(a)	(a)	(a)	1.10
9	2.65	5.20	4.95	3.02	(a)	(a)	(a)	1.03
10	2.64	5.20	4.95	3.00	(a)	(a)	(a)	(b)

a Sand at gage; water in pools.

b Frozen.

Mean daily gage height, in feet, of Platte River near Columbus, 1895–1906—Continued.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1900.								
11	2.64	5.30	5.10	2.73	(a)	2.78	(a)	(b)
12	2.64	5.30	4.95	2.43	(a)	2.25	(a)	(b)
13	2.64	5.05	4.85	2.20	(a)	2.05	(a)	(b)
14	2.64	5.05	4.80	2.10	(a)	1.80	(a)	(b)
15	2.63	5.00	4.95	3.06	(a)	1.48	(a)	(b)
16	2.64	4.95	5.20	3.23	0.03	1.07	(a)	(b)
17	2.68	4.90	5.34	2.30	(a)	1.01	(a)	(b)
18	3.50	4.90	4.96	1.83	(a)	(a)	(a)	.....
19	3.80	4.80	5.00	1.86	(a)	(a)	(a)	.....
20	3.70	4.75	4.90	1.98	(a)	(a)	(a)	.....
21	3.60	4.95	4.82	2.00	(a)	(a)	(a)	.....
22	3.95	5.10	4.60	1.43	(a)	(a)	(a)	.....
23	3.96	5.40	4.42	1.50	(a)	(a)	(a)	.....
24	3.98	5.30	4.30	1.75	(a)	(a)	1.70	.....
25	4.00	5.00	4.20	1.43	0.70	(a)	1.70	.....
26	4.10	4.95	3.96	1.50	.70	(a)	1.70	.....
27	4.25	4.90	3.90	1.65	.53	(a)	1.60	.....
28	4.45	4.70	3.74	1.63	.28	(a)	1.55	.....
29	4.63	4.50	3.60	.98	.03	(a)	1.50	.....
30	4.30	4.45	3.55	.85	.....	(a)	1.45	.....
31	.....	4.40	.....	.50	.....	.....	1.66	.....

Day.	Mar.	Apr.	May.	June.	July.	Nov.	Day.	Mar.	Apr.	May.	June.	July.	Nov.
1901.							1901.						
1	.....	2.40	2.60	3.90	3.40	1.20	17	.....	5.00	3.30	4.30	.....	1.40
2	.....	2.35	2.60	3.90	3.22	1.90	18	.....	4.90	3.40	4.31	.....	1.40
3	.....	2.35	2.55	3.90	3.06	1.90	19	.....	4.70	3.45	4.35	.....	1.40
4	.....	2.40	2.50	3.85	2.90	1.90	20	.....	4.40	3.45	4.40	.....	1.40
5	.....	3.50	2.50	3.80	2.85	1.80	21	.....	3.25	3.50	4.45	.....	1.40
6	.....	3.40	2.60	3.80	2.80	1.75	22	.....	3.25	3.50	4.45	.....	1.40
7	.....	3.40	2.70	3.85	2.79	1.70	23	.....	3.20	3.60	4.45	.....	1.40
8	.....	3.40	2.80	3.85	2.50	1.60	24	2.60	3.20	3.50	4.30	.....	1.50
9	.....	3.45	2.90	3.85	2.40	1.60	25	2.60	3.10	3.50	4.10	.....	1.60
10	.....	3.50	3.10	3.85	2.22	1.60	26	2.70	3.00	3.50	4.00	.....	1.65
11	.....	3.60	3.20	3.90	2.00	1.60	27	2.70	2.80	3.50	3.95	.....	1.70
12	.....	3.80	3.20	3.95	(c)	1.55	28	2.60	2.75	3.60	3.90	.....	1.75
13	.....	4.60	3.20	4.00	.....	1.50	29	2.50	2.75	3.70	3.80	.....	1.80
14	.....	4.80	3.25	4.10	.....	1.50	30	2.50	2.60	3.80	3.60	.....	1.85
15	.....	4.80	3.30	4.20	.....	1.45	31	2.50	.....	3.90	.....	.....	.....
16	.....	5.10	3.30	4.30	.....	1.40							

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.										
1	.....	2.80	2.30	3.38	3.40	1.90	1.10	1.95	1.80	.....
2	.....	2.60	2.25	3.39	3.60	1.80	1.10	2.00	1.90	.....
3	.....	2.40	2.20	3.39	3.60	1.70	1.10	2.20	1.95	.....
4	.....	2.30	2.40	3.40	4.00	1.50	1.00	2.40	2.00	.....
5	.....	2.35	2.50	3.55	4.10	1.35	1.00	2.50	2.00	.....
6	.....	2.10	2.65	3.90	4.10	1.20	1.00	2.75	2.00	.....
7	.....	2.15	2.75	3.80	4.00	1.10	1.10	2.75	2.00	.....
8	3.39	2.15	2.85	3.85	4.00	1.05	1.00	2.50	1.95	.....
9	3.38	2.20	2.85	3.70	3.90	1.00	.90	2.30	1.90	.....
10	3.30	2.20	2.86	3.65	3.75	1.30	.80	2.30	1.90	.....
11	3.00	2.20	2.87	3.50	3.50	1.10	.50	2.40	1.80	.....
12	2.90	2.21	2.90	3.40	3.40	1.00	.45	2.80	1.70	.....
13	2.80	2.22	2.90	3.20	3.20	.90	.40	3.00	1.70	.....
14	2.80	2.20	3.00	3.20	3.21	1.10	.40	3.20	1.80	.....
15	2.80	2.20	3.20	3.05	3.00	1.20	.30	3.30	2.00	.....
16	2.80	2.15	3.35	3.25	2.89	1.10	.20	3.00	2.00	.....
17	2.70	2.15	3.45	3.40	2.80	1.00	.20	2.95	2.10	.....
18	2.40	2.10	4.00	3.55	2.80	1.00	.20	2.90	2.10	.....
19	2.30	2.10	4.30	3.55	3.05	1.00	.40	2.60	2.05	.....
20	2.20	2.15	4.20	3.50	3.38	1.00	.65	2.50	2.05	.....

a Sand at gage; water in pools.
b Frozen.
c Sand around gage, water standing in pools, July 12 to November 1.

Mean daily gage height, in feet, of Platte River near Columbus, 1895–1906—Continued.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.										
21	2.20	2.10	3.85	3.50	3.00	1.40	0.70	2.40	2.10	.....
22	2.10	2.05	3.84	3.50	2.90	2.20	1.00	2.30	2.10	.....
23	2.10	1.95	3.82	3.40	2.80	2.00	1.85	2.20	2.10	.....
24	2.50	1.97	3.80	3.40	2.70	1.90	1.85	2.10	2.10	.....
25	2.70	2.00	3.75	3.40	2.60	1.60	1.85	2.05	2.05	.....
26	3.00	2.10	3.70	3.40	2.50	1.20	1.90	2.05	2.05	.....
27	3.10	2.09	3.60	3.40	2.40	1.30	1.95	2.00	2.00	.....
28	3.10	2.10	3.50	3.42	2.30	1.30	1.95	1.95	1.95	.....
29	3.10	2.15	3.39	3.40	2.20	1.30	1.90	1.85	1.95	.....
30	3.00	2.25	3.38	3.40	2.10	1.30	1.85	1.85	.....	.....
31	2.90	.....	3.38	.....	2.05	1.20	.....	1.85	.....	.....
1903.										
1	.....	3.55	3.70	5.00	3.75	3.94	4.00	2.00	3.10	3.10
2	.....	3.40	3.45	4.75	3.70	3.95	4.10	2.10	3.20	3.10
3	.....	3.30	4.00	4.65	3.70	3.95	4.00	2.10	3.30	3.20
4	.....	3.25	3.90	4.45	4.00	3.95	3.90	2.10	3.30	3.20
5	.....	3.20	3.90	4.25	4.60	3.80	3.60	2.10	3.31	3.20
6	.....	2.85	3.80	4.10	4.65	3.70	3.40	2.10	3.35	.....
7	.....	2.90	3.55	3.90	4.40	3.50	3.00	2.15	3.40	.....
8	.....	3.00	3.75	3.70	4.10	3.40	2.95	2.15	3.40	.....
9	4.11	3.10	4.10	3.60	4.00	3.41	2.90	2.20	3.30	.....
10	.....	3.20	4.10	3.55	3.96	3.10	2.80	2.20	3.30	.....
11	.....	3.00	4.35	3.55	3.96	3.00	2.80	2.30	3.25	.....
12	.....	2.65	4.60	3.45	3.70	3.10	2.80	2.30	3.20	.....
13	.....	2.55	4.62	3.40	3.65	3.35	2.90	2.35	3.00	.....
14	.....	2.50	4.40	3.35	3.65	3.40	3.00	2.40	2.90	.....
15	3.80	2.90	4.35	3.60	3.60	3.80	2.90	2.50	2.90	.....
16	3.85	3.10	4.15	3.60	3.60	3.45	2.80	2.70	2.90	.....
17	3.85	3.10	4.10	3.70	4.13	3.65	2.75	2.75	2.80	.....
18	3.95	3.05	3.85	3.75	4.10	3.60	2.75	2.85	2.70	.....
19	3.90	3.20	3.55	3.80	4.05	3.60	2.72	2.80	2.60	.....
20	4.00	3.20	3.25	3.85	4.00	3.55	2.50	2.80	2.55	.....
21	4.10	3.25	3.10	4.05	3.85	3.40	2.30	2.85	2.55	.....
22	3.80	3.25	3.20	4.20	3.70	3.20	2.20	2.85	2.60	.....
23	3.85	3.35	3.25	4.15	3.65	3.10	2.10	2.85	2.60	.....
24	3.70	3.05	3.30	4.15	3.50	3.10	2.10	2.85	2.70	.....
25	3.65	3.05	3.80	4.30	3.30	3.20	2.00	2.82	2.85	.....
26	3.55	3.05	4.00	4.50	3.20	3.40	2.00	2.80	2.90	.....
27	3.50	3.10	4.10	4.66	3.20	3.80	2.00	2.80	2.95	.....
28	3.45	3.00	4.25	4.45	3.20	3.90	2.00	2.80	3.00	.....
29	3.50	3.00	4.55	4.20	3.10	4.20	2.00	2.80	3.00	.....
30	3.80	3.40	4.75	4.00	3.20	4.20	2.00	2.83	3.05	.....
31	3.55	.....	5.00	.....	3.30	4.00	.....	2.80	.....	.....
1904.										
1	.....	3.20	2.60	4.15	3.91	2.52	1.87	2.05	2.40	.....
2	.....	3.20	2.60	4.20	3.81	2.35	1.80	2.00	2.35	.....
3	.....	3.15	2.60	4.65	3.76	2.40	1.65	1.80	2.30	.....
4	.....	3.20	2.65	4.75	3.75	2.42	1.65	1.80	2.35	.....
5	.....	3.20	2.65	4.85	3.75	2.32	1.70	1.25	2.35	.....
6	.....	3.10	3.00	4.65	3.80	2.29	1.80	1.20	2.35	.....
7	.....	3.10	.....	4.55	3.95	2.26	1.70	1.30	2.40	.....
8	.....	3.30	3.80	4.45	4.02	2.21	1.65	2.00	2.40	.....
9	.....	3.20	3.75	4.35	4.00	2.40	1.53	2.25	2.30	.....
10	.....	3.05	3.75	4.10	3.85	2.85	1.46	2.45	2.20	.....
11	.....	3.05	3.80	4.18	4.20	2.85	1.30	2.25	2.10	.....
12	.....	3.00	3.85	4.35	3.97	2.70	1.12	2.15	2.00	.....
13	3.20	2.90	3.85	4.90	3.80	2.52	1.55	2.20	2.20	.....
14	3.10	2.90	3.90	5.00	3.50	2.40	1.55	2.30	2.30	.....
15	3.10	2.80	3.60	4.60	3.42	2.25	1.35	2.40	2.30	.....
16	3.00	2.80	3.70	4.92	3.35	2.15	1.35	2.35	2.40	.....
17	3.00	2.75	3.60	4.80	3.70	1.95	1.35	2.35	2.55	.....
18	3.00	2.75	3.66	4.50	3.31	2.12	1.30	2.40	2.55	.....
19	3.00	2.70	3.65	4.52	3.20	2.15	1.30	2.45	2.45	.....
20	3.25	2.70	3.65	4.25	3.26	2.17	1.25	2.83	2.42	.....
21	3.30	2.65	3.60	4.20	3.27	2.08	1.50	3.10	2.40	.....
22	3.30	2.60	3.50	4.20	3.25	1.92	1.55	3.10	2.40	.....
23	3.30	2.60	3.38	4.10	3.17	1.65	1.40	3.25	2.40	.....
24	3.20	2.60	3.35	4.10	3.20	1.55	1.40	2.95	2.35	.....
25	3.10	3.00	.....	4.20	3.15	1.45	1.40	2.90	2.40	.....

Mean daily gage height, in feet, of Platte River near Columbus, 1895–1906—Continued.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.										
26	3.00	3.25	3.30	4.55	3.10	1.35	1.45	2.70	2.40	.....
27	3.10	3.45	3.40	4.50	3.03	1.30	1.45	2.60	.....	.....
28	3.10	3.20	3.60	4.25	2.95	1.35	1.50	2.40	.....	.....
29	3.10	2.90	3.70	4.12	3.00	1.40	1.60	2.35	.....	.....
30	3.10	2.75	4.20	4.00	2.91	1.45	1.75	2.30	.....	.....
31	3.10	.....	4.10	.....	2.73	2.00	.....	2.35	.....	.....
1905.										
1	.....	2.6	4.8	5.35	4.6	2.75	1.5	1.7	.....	.....
2	.....	2.4	4.6	5.55	4.65	3.2	.75	1.55	.....	.....
3	.....	2.6	4.4	5.5	4.85	3.2	.7	1.5	.....	.....
4	.....	2.7	4.15	5.35	5.3	3.4	.75	1.5	.....	.....
5	.....	2.6	4.75	5.3	4.95	3.2	1.6	1.3	.....	.....
6	.....	3.0	5.6	5.2	5.5	3.25	1.8	1.3	.....	.....
7	.....	3.2	4.5	5.2	4.7	3.15	2.35	1.25	.....	.....
8	.....	3.1	4.4	5.2	4.55	3.0	2.85	1.2	.....	.....
9	.....	3.1	4.5	4.95	4.2	2.8	2.65	1.35	.....	.....
10	.....	2.9	4.3	5.25	4.15	2.5	2.4	1.2	.....	.....
11	.....	2.9	4.6	5.1	4.0	2.35	2.2	1.15	.....	.....
12	.....	2.8	4.55	5.3	3.75	2.25	1.9	1.15	.....	.....
13	.....	2.6	5.3	5.3	3.55	2.25	1.85	1.2	.....	.....
14	.....	2.7	5.75	5.25	3.35	2.2	2.6	1.35	.....	.....
15	.....	2.6	6.2	5.3	3.15	2.2	2.55	1.4	.....	.....
16	.....	2.6	5.45	5.3	3.0	2.25	2.2	1.3	.....	.....
17	3.1	2.8	5.6	5.8	2.85	2.5	2.25	1.35	.....	.....
18	3.6	2.8	5.15	5.35	2.7	2.55	3.5	1.3	.....	.....
19	3.2	2.8	4.6	5.45	2.5	2.6	3.45	1.35	.....	.....
20	3.8	3.4	4.55	5.15	2.3	2.35	3.35	1.4	.....	.....
21	3.7	3.8	4.35	5.15	2.3	2.35	3.25	1.5	.....	.....
22	3.6	4.0	4.35	4.95	2.2	2.25	3.15	1.6	.....	.....
23	3.7	4.2	4.25	6.35	2.25	2.3	3.0	1.65	.....	.....
24	3.5	4.4	4.2	5.4	2.1	1.95	2.95	1.85	.....	.....
25	3.3	4.6	4.1	5.25	2.1	1.9	2.45	2.0	.....	.....
26	3.1	4.8	4.25	5.25	2.85	2.1	2.2	1.9	.....	.....
27	3.0	5.0	4.15	5.3	3.15	2.2	2.05	1.9	.....	.....
28	2.8	5.3	4.45	5.0	2.85	1.75	1.9	2.0	.....	.....
29	2.7	5.15	5.1	4.95	2.7	1.55	1.75	2.5	.....	.....
30	2.6	5.1	5.25	4.85	2.65	1.35	1.7	2.5	.....	.....
31	2.6	.....	5.5	.....	2.6	1.15	.....	2.5	.....	.....
1906.										
1	.....	.....	5.10	3.90	4.15	2.75	.85	1.90	2.70	.....
2	.....	.....	5.10	4.10	3.75	2.70	1.45	1.90	3.45	.....
3	.....	.....	5.15	4.10	3.70	2.65	1.55	1.85	3.45	.....
4	.....	.....	4.70	4.55	3.55	3.20	1.35	1.70	3.40	.....
5	.....	.....	4.40	4.55	3.45	3.00	1.35	1.65	3.55	.....
6	.....	.....	4.30	4.50	3.30	2.75	1.35	1.70	3.55	.....
7	.....	.....	4.10	4.45	3.20	3.25	1.35	1.70	3.60	.....
8	.....	3.75	3.80	4.65	3.15	3.05	1.40	1.65	3.60	.....
9	.....	3.65	3.80	4.45	3.05	3.00	1.65	1.65	3.50	.....
10	.....	3.60	3.75	4.40	2.95	3.15	1.70	1.75	3.50	.....
11	.....	3.60	3.70	4.10	2.90	2.95	1.60	1.90	3.30	.....
12	.....	3.65	3.65	3.90	2.80	3.00	1.65	1.90	3.30	.....
13	.....	3.80	3.55	3.75	2.90	2.80	1.65	1.85	3.45	.....
14	.....	4.20	3.50	3.60	2.85	2.60	2.05	1.90	3.30	.....
15	.....	3.95	3.35	3.55	2.75	2.60	2.75	1.95	3.30	.....
16	.....	3.65	3.35	3.50	2.70	2.25	2.35	2.10	3.30	.....
17	.....	3.70	3.25	3.65	2.65	2.50	2.60	2.25	3.15	.....
18	.....	3.60	3.20	4.00	3.20	1.95	2.70	2.40	3.10	.....
19	.....	3.45	3.20	3.75	2.80	1.65	2.75	2.45	3.10	.....
20	.....	3.35	3.20	3.85	2.80	1.35	2.50	2.45	3.00	.....
21	.....	3.00	3.15	3.55	2.65	1.35	2.40	2.40	.....	.....
22	.....	3.25	3.15	3.35	2.60	1.35	2.20	2.95	.....	.....
23	.....	3.40	3.05	3.30	2.60	1.35	2.20	3.40	.....	.....
24	.....	3.50	3.55	3.35	2.85	1.20	2.15	3.20	2.90	.....
25	.....	3.30	4.10	4.00	2.80	1.15	2.05	3.35	2.95	.....
26	.....	3.30	3.70	.....	2.75	1.35	2.05	3.35	2.95	.....
27	.....	3.45	3.80	4.50	2.15	1.25	2.15	3.00	2.90	.....
28	.....	3.80	3.10	4.15	2.95	1.05	2.05	3.00	2.90	.....
29	.....	4.50	3.05	3.95	3.05	1.03	1.90	2.70	2.90	.....
30	.....	4.30	3.85	4.00	3.00	1.00	1.90	2.55	3.20	.....
31	.....	.....	3.95	.....	3.00	.90	.....	2.80	.....	.....

Mean daily discharge, in second-feet, of Platte River near Columbus, 1895–1906.

Day.	May.	June.	July.	Aug.	Day.	May.	June.	July.	Aug.
1895.					1895.				
1			9,315	1,250	17		17,130	3,375	845
2			7,900	970	18		16,150	2,950	850
3	5,550		6,600	590	19		16,970	3,545	910
4		9,420	6,210	698	20		16,150	3,205	672
5		8,600	5,170	782	21		14,960	2,700	536
6		7,100	4,165	846	22	5,896	14,440	2,530	878
7		5,170	3,895	564	23		13,470	2,135	1,250
8		7,500	4,345	444	24		12,580	1,980	1,340
9		11,240	3,720	312	25		12,800	1,980	1,070
10		12,580	3,720	472	26		12,250	1,745	725
11		27,200	3,205	236	27		10,590	1,380	508
12		22,400	4,435	264	28		11,550	1,380	416
13		22,420	4,345	96	29		11,750	1,525	360
14		19,280	4,615	1,105	30		11,450	1,525	336
15		17,460	4,985	910	31			1,470	1,140
16		16,150	4,165	910					

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1896.							
1			4,400	0	0	188	2,250
2	4,550		4,400	620	0	188	2,250
3			4,490	2,375	0	305	2,250
4		4,890	4,490	1,850	0	188	2,425
5		4,320	4,280	1,250	0	305	2,500
6		5,260	3,700	1,140	0	425	2,500
7		5,750	3,700	725	0	525	2,640
8		7,050	3,505	425	0	620	2,780
9		9,715	3,190	350	0	725	3,535
10		14,900	3,880	188	0	1,250	2,780
11		11,975	3,570	305	0	1,250	1,600
12		12,185	2,475	420	0	1,030	620
13		10,925	1,975	620	0	1,030	620
14		10,400	1,530	1,715	0	625	620
15		6,100	725	930	0	425	.....
16		8,250	188	188	0	425	.....
17		10,400	0	0	0	425	.....
18		8,250	0	0	0	188	.....
19		7,950	0	0	0	188	.....
20		6,100	0	0	0	188	.....
21		5,750	0	0	0	188	.....
22		5,510	0	0	0	188	.....
23		6,380	0	0	0	350	.....
24		5,750	0	0	0	365	.....
25		6,380	0	0	0	620	.....
26		6,100	0	0	0	620	.....
27		6,450	0	0	0	725	.....
28		6,380	0	0	0	785	.....
29		5,145	0	0	0	845	.....
30		4,535	0	0	0	2,250	.....
31			0	0	0	2,500	.....

Day.	May.	June.	July.	Aug.	Oct.	Day.	May.	June.	July.	Aug.	Oct.
1897.						1897.					
1		21,600	8,200			17	12,250	13,900	2,000	3,300	.....
2		22,600	8,200			18	13,400	9,800	.....	4,400	.....
3		21,400	7,600			19	13,400	8,200	.....	4,400	.....
4	6,700	27,400	6,400			20	12,100	5,500	.....	4,900	.....
5	7,000	22,600	4,700			21	11,250	11,250	.....	4,900	.....
6	7,350	19,700	3,900			22	11,250	12,500	.....	4,900	.....
7	8,200	19,700	3,500			23	10,300	11,500	.....	4,400	.....
8	10,300	20,600	3,500			24	9,250	11,100	.....	3,800	.....
9	12,250	21,600	3,500			25	10,800	11,750	.....	3,400	.....
10	11,250	22,600	3,100			26	12,250	12,200	.....	3,400	.....
11	10,800	23,750	2,550			27	12,100	12,250	.....	3,400	1,400
12	11,250	31,100	2,000			28	14,675	11,750	994	3,400	1,400
13	11,250	28,575	2,000			29	15,250	10,750	.....	1,400	1,600
14	11,250	20,300	2,000			30	18,000	8,700	.....	1,400	1,600
15	12,700	17,750	2,000			31	21,600	.....	.....	1,400	.....
16	12,250	16,000	2,000								

Mean daily discharge, in second-feet, of Platte River near Columbus, 1895–1906—Cont'd.

Day.	May.	June.	July.	Sept.	Oct.	Nov.	Day.	May.	June.	July.	Sept.	Oct.	Nov.
1898.							1898.						
1	1,500	7,800	6,100				17	3,650	11,700	1,400			
2	2,200	24,600	5,000				18	4,500	10,300	1,300	10		
3	4,000	13,900	5,050				19	3,500	9,300	750			
4	4,800	22,200	5,200	2			20	6,850	7,600	500			
5	6,400	20,200	4,900				21	10,700	6,200				
6	6,600	17,100	4,800				22	8,900	6,350				
7	6,800	19,000	3,900				23	7,950	5,750				
8	6,000	15,800	3,650				24	9,600	6,400				
9	5,100	13,100	3,800				25	8,300	6,350				
10	4,950	14,100	3,000				26	6,600	5,700				
11	3,900	13,900	2,770			16	27	9,100	5,100				
12	4,400	12,400	2,350				28	8,100	5,200				
13	3,800	11,900	1,700				29	6,700	5,300	285			
14	3,500	11,400	1,550				30	7,350	5,600			13	
15	3,300	10,900	1,400				31	9,000					
16	3,175	13,200	1,550										

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1899.									
1			7,720	12,415	24,850	6,980			
2			6,505	10,300	20,840	6,570			
3			6,980	9,200	19,190	6,245			
4		11,300	7,330	9,310	20,270	6,770		0	
5		23,700	7,960	5,000	22,440	8,200			
6		18,000	8,600	6,700	23,280	9,420			
7		16,400	10,080	9,200	23,280	8,400			
8		8,200	8,200	7,480	23,700	9,100		0	
9		6,375	8,700	6,375	17,040	9,000			
10		6,635	8,200	6,375	17,360	8,800			
11		6,910	7,720	14,960	17,360	8,040			
12		7,120	7,260	16,560	17,200	10,400			
13		7,330	6,840	19,890	17,040	6,245			
14		4,559	6,505	22,860	16,880	5,775		0	
15		3,950	6,050	23,490	15,920	5,350			
16		3,600	6,310	23,700	16,080	3,500			
17		3,750	5,150	23,490	14,665	3,900		0	
18		4,150	4,950	9,310	12,644	3,460			
19		6,715	4,750	9,200	11,400	3,700		0	
20		7,400	4,700	9,200	11,400	3,340	0		
21		9,100	8,800	11,200	10,400	3,380		0	
22		7,960	10,800	13,220	9,310	3,340			
23		8,200	7,880	14,395	8,600	3,140			
24		7,880	15,600	16,240	8,300	2,938	0		
25		8,040	18,850	12,875	7,400	2,547		0	
26		14,125	22,400	13,105	7,480	2,361			
27		7,800	25,770	13,855	7,560	1,861	0		
28		7,260	20,745	18,170	3,380			0	
29		7,800	18,340	19,190	8,800				
30		7,960	16,720	25,540	8,900		0		
31			15,120		8,120				
1900.									
1			7,800	11,600	5,400				950
2			7,400	12,415	5,900				600
3			7,330	13,850	5,700				500
4			7,260	13,720	5,900				400
5			14,800	13,000	10,500				400
6			15,280	13,850	6,500				400
7			35,400	18,000	3,620				350
8		1,907	27,500	16,880	3,850				300
9		1,800	25,100	15,760	4,625				300
10		1,738	25,100	15,600	4,700				
11		1,738	27,500	18,170	3,550		4,600		
12		1,707	27,500	15,920	2,440		2,350		
13		1,676	21,800	14,665	1,750		1,700		
14		1,648	21,600	14,125	1,550		1,030		
15		1,594	20,650	16,720	5,610		550		

Mean daily discharge, in second-feet, of Platte River near Columbus, 1895–1906—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1900.									
16		1,594	19,700	21,600	2,000		403		
17		1,707	18,850	25,770	2,280		400		
18		5,100	18,850	18,510	950				
19		6,770	17,200	20,080	1,000				
20		6,050	16,400	18,850	1,300				
21		5,500	19,700	18,340	400				
22		7,720	22,440	15,600	500				
23		7,720	29,440	13,450	520				
24		7,880	26,960	12,530	800			920	
25		7,960	20,270	11,600	500			920	
26		8,800	19,360	9,600	550	149		950	
27		10,800	18,510	9,275	660			770	
28		12,875	15,120	7,800	650			680	
29		14,530	12,415	6,900	394			610	
30		10,800	12,875	6,700	250			600	
31			11,200		200			998	
1901.									
1		1,483	2,361	9,100	4,500				375
2		1,300	2,394	9,000	3,600				978
3		1,300	2,228	8,900	2,938				978
4		1,455	2,054	8,300	2,324				978
5		6,180	2,088	7,720	2,154				850
6		5,555	2,435	7,560	1,984			20	800
7		5,555	2,857	8,241	1,946				750
8		5,555	3,260	7,800	1,270				700
9		5,775	3,750	7,720	1,150				700
10		6,050	6,799	7,640	920				700
11		6,700	5,250	7,960	725				700
12		8,200	5,250	8,300					590
13		18,000	5,200	8,700					570
14		21,600	5,450	9,640	379				570
15		21,600	5,665	10,600					550
16		28,400	5,665	11,500					500
17		26,000	5,610	11,400					500
18		21,810	6,115	11,949					500
19		19,790	6,375	11,821					500
20		14,960	6,310	12,300					500
21		4,824	6,635	12,875					500
22		4,850	6,570	12,875					500
23		4,600	7,190	12,875					500
24	2,054	4,650	6,440	11,300					600
25	2,054	4,150	6,375	9,200					680
26	2,398	3,700	6,110	8,200					720
27	2,436	2,898	6,245	7,800					770
28	2,123	2,736	6,840	7,400					820
29	1,799	2,816	7,480	6,700					870
30	1,800	2,324	8,200	5,500					922
31	1,816		9,200						
1902.									
1		2,398	1,312	5,852	5,995	845	253	975	635
2		1,738	1,262	5,885	7,330	745	257	1,025	725
3		1,287	1,212	5,885	7,330	626	257	1,275	775
4		1,162	1,593	5,400	11,140	482	226	1,676	825
5		1,212	1,922	6,910	11,140	376	229	1,989	825
6		915	2,473	9,950	11,140	291	229	2,816	825
7		965	2,898	8,960	11,140	250	260	2,816	825
8	5,664	955	3,340	9,450	11,140	235	232	1,826	775
9	5,610	1,005	3,340	8,040	10,050	220	202	1,337	725
10	5,100	995	3,429	7,640	8,580	350	175	1,337	725
11	3,650	995	3,500	6,570	6,992	250	5	1,400	635
12	3,180	996	3,600	5,940	5,995	220		2,696	550
13	2,776	996	3,550	4,900	4,900	190		3,500	550
14	2,736	985	3,950	4,900	4,950	250		4,500	635
15	2,736	996	4,900	4,150	3,900	285		5,000	825
16	2,696	955	4,555	5,150	3,340	250		3,100	825
17	2,324	965	6,050	5,940	2,978	220		2,898	925
18	1,387	925	10,480	6,910	2,978	220		2,698	925
19	1,262	935	13,800	6,910	4,050	220		1,676	875
20	1,125	995	12,400	6,635	5,720	220	120	1,400	875

Mean daily discharge, in second-feet, of Platte River near Columbus, 1895–1906—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.									
21	1,125	955	8,580	6,635	3,800	400	138	1,275	925
22	995	1,015	8,447	6,635	3,300	1,150	244	1,150	925
23	995	825	8,200	5,995	2,898	925	865	1,025	925
24	1,565	855	8,120	5,995	2,510	825	865	925	925
25	2,188	895	7,800	5,995	2,120	550	865	875	875
26	3,300	1,005	7,480	5,995	1,799	285	925	875	875
27	3,750	1,005	6,840	5,500	1,510	340	975	825	825
28	3,700	1,025	6,245	6,050	1,300	340	975	775	775
29	3,700	1,100	5,665	5,995	1,187	340	925	690	775
30	3,220	1,237	5,665	5,995	1,062	346	875	690	.....
31	2,817	.....	5,720	.....	995	290	.....	690	.....
1903.									
1	.....	7,800	6,700	21,600	5,250	6,375	4,500	190	1,680
2	.....	6,700	5,250	17,200	5,000	6,375	4,750	220	1,980
3	.....	6,050	9,150	15,600	5,000	6,375	4,250	220	2,320
4	.....	5,775	7,800	12,960	7,050	6,050	3,750	220	2,320
5	.....	5,500	7,800	10,700	12,960	5,250	2,510	220	2,320
6	.....	3,750	7,050	9,150	13,550	4,750	1,830	220	2,900
7	.....	4,000	5,500	7,050	10,700	3,500	1,040	235	3,100
8	.....	4,250	6,700	5,775	7,800	3,100	985	235	3,100
9	10,150	4,750	9,650	5,250	7,050	3,100	930	250	2,700
10	.....	5,250	9,650	5,000	7,050	1,830	820	250	2,700
11	.....	4,250	12,390	5,000	7,050	1,540	820	285	2,510
12	.....	2,510	15,600	4,500	5,500	1,830	770	285	2,320
13	.....	2,150	15,600	4,250	5,000	2,510	875	310	1,980
14	.....	1,980	12,960	4,000	5,000	2,700	985	400	1,680
15	7,400	3,500	12,390	5,250	4,750	4,500	875	475	1,680
16	10,700	4,250	10,150	5,000	4,750	2,700	770	635	1,680
17	10,700	4,250	9,650	5,500	7,800	3,500	680	680	1,415
18	11,820	4,000	7,400	5,775	7,400	3,100	680	875	1,285
19	11,250	4,750	5,500	6,050	7,050	3,100	635	820	1,155
20	12,390	4,500	4,000	6,375	6,700	2,900	475	820	1,095
21	13,550	4,750	3,300	7,400	5,775	2,320	340	985	1,095
22	10,150	4,750	3,750	8,675	5,000	1,680	285	985	1,155
23	10,700	5,250	4,000	8,200	4,750	1,350	250	985	1,155
24	9,150	3,500	4,250	8,200	4,000	1,350	235	985	1,285
25	8,675	3,500	6,700	9,650	3,100	1,540	205	930	1,540
26	7,800	3,500	8,200	11,820	2,700	2,150	205	1,040	1,680
27	7,400	3,750	9,150	12,960	2,700	3,750	205	1,040	1,830
28	7,050	3,100	10,700	10,700	2,700	4,000	205	1,040	1,980
29	7,400	3,100	14,175	8,200	2,320	5,500	190	1,040	1,980
30	10,150	5,000	17,200	6,700	2,700	5,500	190	1,095	2,150
31	7,800	.....	21,600	.....	3,100	4,500	.....	1,040	.....
1904.									
1	.....	.....	.....	8,550	10,130	1,000	50	150	1,000
2	.....	.....	.....	8,945	9,340	600	50	100	1,000
3	.....	.....	.....	13,290	8,945	700	(a)	50	1,000
4	.....	.....	.....	14,080	8,945	700	(a)	50	1,000
5	.....	.....	.....	15,265	8,945	500	(a)	0	1,000
6	.....	.....	.....	13,290	9,340	500	(a)	0	1,000
7	.....	.....	.....	12,105	10,525	425	(a)	0	1,000
8	.....	.....	5,390	11,315	10,920	350	(a)	100	1,000
9	.....	.....	4,995	10,525	10,920	700	(a)	425	1,000
10	.....	.....	4,995	7,760	9,735	2,075	(a)	800	1,000
11	.....	.....	5,390	8,550	12,500	2,075	(a)	425	1,000
12	.....	.....	5,785	10,130	10,525	1,400	(a)	275	1,000
13	.....	.....	5,785	15,660	9,340	900	(a)	350	1,000
14	.....	.....	6,180	16,450	6,970	700	(a)	500	1,000
15	.....	.....	3,430	15,660	6,180	425	(a)	700	1,000
16	.....	.....	4,600	18,030	5,785	275	(a)	600	1,000
17	.....	.....	3,430	17,240	8,550	50	(a)	600	1,000
18	.....	.....	3,810	14,870	5,390	200	(a)	700	1,000
19	.....	.....	3,810	14,870	4,600	275	(a)	800	1,000
20	.....	.....	3,810	12,895	4,995	275	(a)	2,075	1,000
21	.....	.....	3,430	12,500	4,995	200	(a)	3,810	1,000
22	.....	.....	2,700	12,500	4,995	(a)	(a)	3,810	1,000
23	.....	.....	1,800	11,710	4,205	0	(a)	4,995	1,000
24	.....	.....	1,400	11,710	4,600	0	(a)	2,700	1,000
25	.....	.....	.....	12,500	4,205	0	(a)	2,350	1,000

a Pools.

Mean daily discharge, in second-feet, of Platte River near Columbus, 1895–1906—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1904.									
26			1,250	15,265	3,810	0	(a)	1,400	1,000
27			1,800	14,870	3,430	0	(a)	1,100	.....
28			3,430	12,895	2,700	0	(a)	1,000	.....
29			4,205	11,710	3,050	0	(a)	1,000	.....
30			8,550	10,920	2,350	0	(a)	1,000	.....
31			7,760	.....	1,600	100	.....	1,000	.....
1905.									
1	.....	2,280	18,450	32,100	20,450	4,270	260	670	.....
2	.....	1,750	15,500	35,600	21,150	6,700	0	360	.....
3	.....	2,280	13,170	34,700	24,050	6,700	0	260	.....
4	.....	2,580	10,850	32,100	31,250	8,040	0	260	.....
5	.....	2,280	17,670	31,250	25,580	6,700	460	0	.....
6	.....	3,650	33,550	29,600	34,700	7,020	900	0	.....
7	.....	4,510	14,260	29,600	21,850	6,395	2,590	0	.....
8	.....	4,060	13,170	29,600	19,780	5,520	4,745	0	.....
9	.....	4,060	14,260	25,580	15,450	4,500	3,820	6	.....
10	.....	3,270	12,190	30,420	14,900	3,180	2,780	0	.....
11	.....	3,270	15,500	27,950	13,280	2,590	2,050	0	.....
12	.....	2,910	14,880	31,250	10,880	2,220	1,150	0	.....
13	.....	2,280	27,400	31,250	9,170	2,225	1,025	0	.....
14	.....	2,580	36,800	30,420	7,690	2,050	3,600	0	.....
15	.....	2,280	47,200	31,250	6,390	2,050	3,390	80	.....
16	.....	2,280	30,420	31,250	5,520	2,220	2,050	0	.....
17	4,060	2,910	33,550	40,150	4,740	3,180	2,225	0	.....
18	6,720	2,910	24,520	32,100	4,040	3,390	8,780	0	.....
19	4,510	2,910	15,500	33,820	3,180	3,600	8,410	0	.....
20	8,080	5,530	14,880	28,780	2,400	2,590	7,700	80	.....
21	7,380	8,080	12,680	28,780	2,400	2,590	7,025	260	.....
22	6,720	9,600	12,680	25,570	2,050	2,225	6,400	460	.....
23	7,380	11,280	11,740	51,100	2,220	2,400	5,520	565	.....
24	6,100	13,170	11,280	32,950	1,730	1,290	5,260	1,025	.....
25	5,000	15,500	10,420	30,420	1,730	1,150	2,980	1,430	.....
26	4,060	18,450	11,740	30,420	4,740	1,730	2,050	1,150	.....
27	3,650	21,800	10,850	31,250	6,390	2,050	1,580	1,150	.....
28	2,910	27,400	13,720	26,350	4,740	785	1,150	1,430	.....
29	2,580	24,500	23,600	25,580	4,040	360	785	3,180	.....
30	2,280	23,600	26,420	24,050	3,820	0	670	3,180	.....
31	2,280	.....	31,450	.....	3,600	0	.....	3,180	.....
1906.									
1	.....	.....	22,300	8,090	10,100	2,440	8	630	2,290
2	.....	.....	22,300	9,690	7,040	2,290	155	630	4,240
3	.....	.....	23,200	9,690	6,700	2,160	235	565	4,240
4	.....	.....	16,100	14,200	5,790	4,040	95	380	4,970
5	.....	.....	12,500	14,200	4,240	3,240	95	330	5,790
6	.....	.....	11,500	13,600	4,490	2,440	95	380	5,790
7	.....	.....	9,690	13,100	4,040	4,260	95	380	6,080
8	.....	7,040	7,370	15,400	3,830	3,430	120	330	6,080
9	.....	6,390	7,370	13,100	3,430	3,240	330	330	5,500
10	.....	6,080	7,040	12,500	3,070	3,830	380	440	5,500
11	.....	6,080	6,700	9,690	2,900	3,070	280	630	4,490
12	.....	6,390	6,390	8,090	2,580	3,240	330	630	4,490
13	.....	7,370	5,790	7,040	2,900	2,580	330	565	4,240
14	.....	10,600	5,500	6,080	2,740	2,020	850	630	4,490
15	.....	8,480	4,730	5,790	2,440	2,020	2,440	700	4,490
16	.....	6,390	4,730	5,500	2,290	1,210	1,420	930	4,490
17	.....	6,700	4,260	6,390	2,160	1,770	2,020	1,210	3,830
18	.....	6,080	4,040	8,860	4,040	700	2,290	1,530	3,620
19	.....	4,240	4,040	7,040	2,580	330	2,440	1,650	3,620
20	.....	4,730	4,040	7,730	2,580	95	1,770	1,650	3,240
21	.....	3,240	3,830	5,790	2,160	95	1,530	1,530	3,160
22	.....	4,260	3,830	4,730	2,020	95	1,110	3,070	3,070
23	.....	4,970	3,430	4,490	2,020	95	1,110	4,970	2,980
24	.....	5,500	5,790	4,910	2,740	40	1,020	4,040	2,900
25	.....	4,490	9,690	8,860	2,580	32	850	4,730	3,070
26	.....	4,490	6,770	11,100	2,440	95	850	4,730	3,070
27	.....	4,240	7,370	13,600	1,020	55	1,020	3,240	2,900
28	.....	7,370	3,620	10,100	3,070	20	850	3,240	2,900
29	.....	13,600	3,430	8,480	3,430	18	630	2,290	2,900
30	.....	11,500	7,730	8,860	3,240	15	630	1,900	4,040
31	.....	.....	8,480	.....	3,240	10	.....	2,580	.....

a Pools.

Estimated monthly discharge of Platte River near Columbus, 1895–1906.

[Drainage area, 56,900 square miles.]

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
March.								
1901 [a]	2,440	1,800	2,060	32,700				1.59
1902 [b]	5,660	995	2,817	134,100				1.19
1903 [c]	13,550	7,050	9,652	325,500				.94
1905 [d]	8,080	2,280	4,914	146,200				1.31
April.								
1898 [e]	2,700	500	1,477	87,900				1.65
1899	23,700	3,600	8,600	511,700	0.151	0.17	2	.83
1900 [f]	14,530	1,590	5,584	332,300				5.79
1901	28,400	1,300	8,827	525,200	.155	.18	7	2.64
1902	2,400	825	1,076	64,000	.019	.02	2	1.07
1903	7,800	1,980	4,339	258,200	.076	.08	5	1.48
1905	27,400	1,760	7,800	464,100	.137	.15	4	3.70
1906	13,600	3,240	6,530	388,600	.115	.13	3	4.35
May.								
1897	21,600	6,700	11,801	725,600	.207	.24	12	1.97
1898	10,700	1,500	5,851	359,800	.103	.12	3	4.40
1899	25,770	4,700	10,373	637,800	.182	.21	7	2.86
1900	35,400	7,300	19,039	1,170,600	.333	.38	28	1.37
1901	9,200	2,050	5,300	325,900	.093	.10	5	2.09
1902	13,800	1,210	5,462	335,800	.096	.11	3	3.40
1903	21,600	3,300	9,159	563,200	.161	.19	4	4.60
1904	8,550	1,250	4,128	253,800	.073	.08	2	3.37
1905	47,200	10,420	19,360	1,190,000	.340	.39	7	5.73
1906	23,200	3,430	8,180	503,000	.144	.17	6	2.76
June.								
1895	27,200	5,170	14,027	834,700	.247	.28	7	4.04
1896	14,900	4,320	7,510	446,900	.132	.15	6	2.65
1897	31,100	5,500	16,904	1,005,800	.296	.33	12	2.77
1898	24,600	5,100	11,278	671,100	.200	.22	7	3.03
1899	25,540	5,000	13,747	818,800	.241	.27	10	2.66
1900	25,570	6,700	14,696	874,500	.258	.29	19	1.51
1901	12,880	5,500	9,363	857,100	.164	.18	6	2.96
1902	9,950	4,150	6,426	382,300	.113	.13	4	3.38
1903	21,600	4,000	8,816	524,600	.155	.17	8	2.20
1904	18,190	7,760	12,880	766,400	.226	.25	7	3.64
1905	51,100	24,050	31,180	1,855,000	.548	.61	12	5.04
1906	15,400	4,490	9,220	549,000	.162	.18	7	2.70
July.								
1895	9,320	1,380	3,685	226,600	.065	.08	7	1.12
1896	4,490	0	1,629	100,200	.029	.03	1	3.43
1897	8,200	990	2,771	170,400	.049	.06	3	2.36
1898 [g]	6,100	500	3,029	186,200				1.59
1899	24,850	3,380	14,551	894,700	.255	.30	12	2.55
1900	10,500	200	2,883	177,300	.050	.06	2	2.63
1901 [h]	4,500	725	1,991	47,400				1.29
1902	11,140	995	5,267	323,800	.093	.11	3	3.84
1903	13,550	2,320	5,847	359,500	.103	.12	3	3.71
1904	12,500	1,520	6,888	423,500	.121	.14	5	3.14
1905	34,700	1,730	10,770	662,200	.189	.22	5	4.67
1906	10,100	1,020	3,480	214,000	.061	.07	3	2.70
August.								
1895	1,340	96	722	44,400	.012	.01	.6	1.63
1896	2,380	0	423	26,000	.007	.01	.6	1.74
1897			(i)					2.46
1898			(i)					1.84
1899	10,400	1,869	5,658	347,900	.100	.01	.5	2.04
1900			(i)					2.20
1901			(i)					1.80
1902	1,150	190	404	24,800	.007	.01	.6	1.65
1903	6,380	1,350	3,507	215,600	.062	.07	2	3.52
1904	2,080	0	451	27,700	.008	.01	.5	2.11
1905	8,040	0	3,217	197,800	.057	.07	3	2.79
1906	4,220	10	1,580	97,200	.028	.03	1	3.66

[a] March 24 to 31.
[b] March 8 to 31.
[c] March 15 to 31.
[d] March 17 to 31.
[e] April 17 to 30.
[f] April 8 to 30.
[g] July 1 to 20.
[h] July 1 to 11.
[i] Water in pools or tiny channels.

Estimated monthly discharge of Platte River near Columbus, 1895–1906—Continued.

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
September.								
1896			(a)					2.10
1897			(a)					.81
1898			(a)					1.06
1899			(a)					.60
1900 [b]			1,588	22,100				2.41
1901			(a)					2.82
1902	975	0	337	20,500	0.006	0.01	0.3	3.22
1903	4,750	190	1,175	69,900	.021	.02	2	1.27
1904	41	0	200					1.56
1905	8,780	0	2,978	177,200	.052	.06	2	3.79
1906	2,440	0.8	846	50,300	.015	.02	1	2.00
October.								
1896	2,500	188	649	38,900	.011	.01		1.37
1897			(a)					2.04
1898			(a)					.73
1899			(a)					.40
1900 [c]			806	12,800				1.56
1901			(a)					1.09
1902	5,000	690	1,798	110,600	.032	.04	2	1.88
1903	1,100	190	613	37,700	.011	.01	1	1.00
1904	4,990	0	1,037	63,800	.018	.02	1	1.87
1905	3,180	0	604	37,100	.011	.01	1	1.23
1906	4,970	330	1,640	101,000	.029	.03	1	2.40
November.								
1896 [d]	3,540	620	2,098	58,300				.87
1900 [e]			472	8,400				.19
1901	978	375	672	40,000	.012	.01	2	.53
1902	925	635	795	47,400	.014	.02	5	.35
1903	3,100	1,090	1,926	114,600	.034	.04	7	.55
1904			1,000	59,500	.018	.02	25	.08
1905	6,080	2,290	4,080	243,000	.072	.08	12	.64

[a] Water in pools or tiny channels
[b] September 11 to 17.
[c] October 24 to 31.
[d] November 1 to 14.
[e] November 1 to 9

PLATTE RIVER AT SOUTHBEND.

The station at Southbend was established March 25, 1903, and discontinued September 30 of the same year. When the station was selected it was expected that measurements could be made from a foot bridge which was then out of repair; but as the repairs were not made and as there was no other practical method of making measurements, it was necessary to abandon the station. Its location at Southbend, below all important tributaries of the Platte, is shown on the Fremont topographic sheet of the United States Geological Survey.

The channel at the gage is straight. The right bank is low and subject to overflow; the left bank is a high limestone bluff. The bed is of shifting sand and a large number of measurements would be required for accurate results.

The gage was an inclined staff, graduated to half-tenths, located on the left bank in the NE. $\frac{1}{4}$ sec. 13, T. 12 N., R. 10 E., one-fourth mile north of the Burlington and Missouri River Railroad depot at Southbend. The gage was referred to bench marks as follows: (1) The sill

of the north window of the Burlington and Missouri River Railroad depot; elevation, 10.47 feet above the zero of the gage. (2) The northeast corner of the southeast cornerstone of the left masonry abutment to an old bridge 100 feet downstream from the gage; elevation, 13.78 feet above the zero of the gage.

Discharge measurements of Platte River at Southbend, 1903.

Date.	Hydrographer.	Gage height.	Discharge.
1903.		*Feet.*	*Second-feet.*
May 5	J. C. Stevens	3.80	13,178
August 31	do	4.90	38,846
September 14	do	2.30	11,986

Mean daily gage height, in feet, of Platte River at Southbend, 1903.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
1		3.15	3.40	6.50	3.15	2.55	4.50
2		3.05	3.25	5.95	2.90	5.50	4.15
3		3.00	3.25	5.70	2.85	4.55	3.20
4		2.10	3.45	5.20	3.05	4.25	2.90
5		2.10	3.80	4.70	5.00	3.85	2.30
6		2.90	3.55	4.45	4.40	3.45	2.05
7		2.70	3.35	3.80	4.00	3.25	1.85
8		2.55	3.25	3.65	3.65	2.90	1.70
9		2.50	3.15	3.50	3.15	2.45	2.00
10		2.50	3.15	3.20	2.65	2.25	1.95
11		2.50	3.85	3.05	2.75	1.95	1.85
12		2.52	4.70	2.85	2.55	2.00	1.95
13		2.75	4.65	2.70	2.35	1.95	2.00
14		2.60	4.45	2.55	2.25	4.00	2.30
15		2.45	4.15	2.35	2.15	3.60	2.55
16		2.50	4.10	2.25	2.15	3.60	2.75
17		2.55	3.40	2.00	3.05	3.15	2.90
18		2.55	3.15	2.05	3.55	2.75	2.45
19		2.55	3.40	2.35	3.70	2.50	1.90
20		2.55	3.50	2.20	3.45	2.20	1.60
21		2.60	3.60	2.55	2.25	2.20	1.50
22		2.60	3.95	3.00	2.90	1.90	1.40
23		2.65	4.05	3.25	2.45	1.80	1.35
24		2.70	4.00	2.95	2.35	1.70	1.15
25	3.55	2.60	4.50	3.30	1.70	1.45	1.05
26	3.65	2.35	5.40	3.60	1.35	1.75	1.05
27	3.65	2.35	5.15	3.75	1.25	2.30	1.05
28	3.15	2.45	5.40	3.65	1.25	5.55	.95
29	3.25	2.95	5.60	3.60	1.95	5.45	.90
30	3.15	3.50	6.55	3.60	1.75	5.15	.90
31	3.45	.....	6.60	.....	2.60	4.90	.....

NORTH PLATTE DRAINAGE BASIN.

DESCRIPTION OF BASIN.

North Platte River rises in the northern part of North Park, in Colorado, flows north and then east through Wyoming and the west-central part of Nebraska, and unites with South Platte River in Lincoln County, Nebr., to form the Platte.

The headwaters of this river are mountainous streams, flowing in narrow canyons or gorges and receiving numerous canyon tributaries

almost to the Nebraska state line, where it becomes a wide, shallow, sandy stream, spreading over the plains. Its drainage basin thus includes both the mountainous, forested type and the grass-grown areas and embraces 28,500 square miles.

The topography and geology of its headwater area are essentially those of the Rocky Mountain region, which have been described many times by scientific and popular writers. Throughout its course in western Nebraska the river has eroded a valley 10 to 15 miles wide and more than 300 feet deep. The present valley floor, consisting of sediments deposited in a former, greater valley, is bordered by terraces and table-lands that are scarred by numerous tributaries and arroyos. In the upper terrace are pebbles and cobblestones that point to the former existence of a deep, swift stream; in the lower terrace the material is fine; and in the present valley the bed is almost entirely of sand and the stream is broad and shallow, with a flood plain from a mile to 4 miles wide. These table-lands and terraces are composed of pinkish clays, hard and more or less sandy, dotted here and there with characteristic remains of an overlying formation of impure limestone that forms many distinct landmarks of the North Platte Valley, among which may be mentioned Chimney Rock, Court House and Jail, and Castle Rock. Beyond these table-lands and terraces, particularly on the north, are sand hills, in many places extending almost to the river valley.

The soil of the North Platte Valley is sandy but very fertile and requires only the application of water to make it highly productive. There is little or no forest land except on the headwaters, and the timber that exists has been planted by man. Outside of the immediate river valley the country is given over almost entirely to range land for cattle. In the valley of the river large quantities of hay, grains, corn, etc., are raised, mostly by the aid of irrigation.

The precipitation on the headwaters comes chiefly in the form of snow during the winter months. In the lower portion of the stream basin the precipitation is from 15 to 18 inches and the evaporation is from 5 to 6 feet.

The North Platte is subject to floods which occur periodically, reaching their maximum at the mouth of the stream sometime during the latter part of June. After these floods have subsided the flow greatly diminishes until about the first of September, when the river is almost dry so far as surface flow is concerned. The waters of the stream are extensively used for irrigation, but owing to the fluctuation of the discharge storage is necessary to make the entire supply available for use. To this end a large storage reservoir is being built by the United States Reclamation Service in Wyoming, whence waters will be taken in canals to supply the needs of the valley. The principal tributaries of North Platte River are the Sweetwater and the

Laramie, in Wyoming. Just below the mouth of the Sweetwater is the site of the Pathfinder dam. In Nebraska the tributaries are a few small creeks.

The following table shows the number and location of the stations which have been and are at present maintained on this stream in Nebraska:

Gaging stations on North Platte River in Nebraska.

Station.	County.	Established.	Discontinued.
Mitchell	Scotts Bluff	June 3, 1901	
Gering	do	May 29, 1897	May 25, 1901
Camp Clarke	Cheyenne	June 27, 1896	Nov. 10, 1900
Bridgeport	do	May 4, 1902	
North Platte	Lincoln	Oct. 5, 1894	

NORTH PLATTE RIVER AT MITCHELL.

Observations were begun near this point on the North Platte on May 29, 1897, when the Gering station was established. On June 3, 1901, this was replaced by the station at Mitchell, where conditions were more favorable and which had the added advantage of being nearer the Nebraska-Wyoming state line. The station at Mitchell is located at the highway bridge 1 mile south of the town, in sec. 27, T. 23 N., R. 56 W., and is shown on the Scotts Bluff topographic atlas sheet of the United States Geological Survey.

At the gaging section the stream flows in three channels and the alignment is straight for a considerable distance both above and below. The bed is composed of shifting sand, 20 feet or more in depth. The banks are low but not liable to overflow. The water is never sluggish, even at extreme low stages, when it runs in numerous tiny channels. The range of gage heights is about 6 feet. Attempts to obtain reliable records of winter flow have heretofore proved unsuccessful, as at times during the winter the river freezes solid.

Discharge measurements are made from the upstream side of a long pile bridge, supported on bents spaced 20 feet apart.

The gage is of the standard weight and chain type, fastened to the upstream end of the hand rail near the center of the bridge. The length of the chain from the index to the end of the weight is 10.60 feet. The gage is referred to bench marks as follows: (1) A cross cut in the floor of the bridge at the gage; elevation, 9.74 feet above the zero of the gage. (2) A standard aluminum bench-mark cap, marked United States Geological Survey, leaded into the top of a 2-inch gas pipe 4 feet long, located 138 feet north and 30 feet east of the left end of the downstream hand rail; elevation, 8.64 feet above the zero of the gage.

During 1901 the gage datum was 1 foot higher than during subsequent years, a fact which resulted in negative gage heights. Accordingly, on May 3, 1902, the gage datum was lowered 1 foot. All gage heights so affected have been corrected to the present gage datum, which is 8.64 feet below bench mark No. 2.

Discharge measurements of North Platte River at Mitchell, 1901–1906.

Date.	Hydrographer.	Gage height.	Discharge.
1901.		*Feet.*	*Sec.-ft.*
June 3	O. V. P. Stout	3.67	10,521
June 21	R. H. Willis	3.32	8,478
July 2	do	2.27	4,114
July 11	do	1.37	1,768
July 19	H. O. Smith	.66	1,048
August 3	R. H. Willis	.72	1,038
August 12	do	.45	566
August 24	do	.28	351
September 3	do	.23	227
September 11	do	.38	422
September 24	do	.25	341
October 11	do	.29	302
October 29	do	.39	438
November 26	do	.45	576
1902.			
April 4	Frank Dobson	1.56	917
May 3	do	2.22	2,649
May 28	do	2.46	3,698
June 12	do	3.15	6,426
June 19	do	3.00	4,895
June 27	do	2.42	3,270
July 16	do	1.58	1,014
July 24	do	1.30	630
August 8	do	1.05	349
August 19	do	.85	102
September 2	do	.82	29
October 25	R. H. Willis	.96	372
1903.			
March 31	J. C. Stevens	1.76	1,735
May 12	do	2.60	3,580
June 20	do	3.68	9,637
July 7	do	2.72	4,230
July 30	do	1.50	1,067
August 12	J. C. Stevens	1.20	456
August 21	do	.87	184
August 22	do	.88	215
September 3	O. V. P. Stout	.82	158
1904.			
March 29	M. D. McWilliams	2.30	1,273
April 23	J. C. Stevens	2.58	1,890
May 9	M. D. McWilliams	3.40	5,070
May 23	do	4.75	11,891
June 9	J. C. Stevens	3.15	4,540
September 27	R. D. Hubbard	1.75	209
September 29	A. J. Parshall	1.72	214
September 30	do	1.80	266
1905.			
March 29	H. C. Gardner	2.40	1,186
May 12	do	4.15	8,619
June 13	do	5.20	16,770
July 11	do	3.25	3,852
July 20	do	2.50	1,622
August 3	do	2.75	2,014
September 21	F. S. Dobson	1.92	383
September 7	H. C. Gardner	1.95	507
1906.			
April 12	F. S. Dobson	3.35	3,168
May 8	do	3.45	3,991
do	do	3.45	4,261
June 26	Arthur Dobson	4.05	6,786
July 24	do	3.12	2,630
September 1	do	2.45	852
October 16	Arthur Wilson	2.53	643
December 8	do	2.95	2,077

Mean daily gage height, in feet, of North Platte River at Mitchell, 1901–1906.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Day.	June.	July.	Aug.	Sept.	Oct.	Nov.
1901.							1901.						
1	.....	2.40	.....	0.18	0.23	0.40	17	3.40	1.06	0.35	0.27	0.40	.....
2	.....	2.27	.....	.19	.23	.40	18	3.60	1.05	.34	.25	.40	.....
3	3.67	2.21	0.72	.23	.23	.....	19	3.50	1.03	.35	.25	.40	.....
4	.....	2.09	.....	.20	.24	.....	20	3.40	1.01	.34	.28	.43	.....
5	.....	2.01	.....	.30	.24	.....	21	3.32	.....	.35	.25	.40	.....
6	.....	2.90	.....	.35	.25	.....	22	3.22	.....	.30	.25	.40	.....
7	.....	1.94	.....	.37	.25	.....	23	2.90	.....	.30	.24	.40	.....
8	.....	1.82	.....	.37	.24	.....	24	2.75	.....	.28	.25	.40	.....
9	3.50	1.65	.....	.34	.23	.....	25	2.60	.....	.25	.25	.40	.....
10	3.30	1.57	.....	.35	.25	.....	26	2.55	.....	.25	.23	.40	0.45
11	3.15	1.48	.....	.38	.29	.....	27	2.42	.....	.23	.25	.40	.....
12	3.15	1.31	.45	.34	.22	.....	28	2.41	.....	.20	.22	.40	.....
13	3.00	1.22	.30	.30	.33	.....	29	2.40	.....	.20	.22	.40	.....
14	3.00	1.22	.35	.28	.40	.....	30	2.40	.....	.28	.24	.40	.....
15	4.00	1.11	.35	.28	.45	.....	31	.....	.....	.18	.....	.38	.....
16	3.30	1.08	.38	.27	.40	.....							

Mean daily gage height, in feet, of North Platte River at Mitchell, 1901–1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1					2.26	2.79	2.30	1.21	0.82	0.86	0.95	
2					2.36	2.91	2.65	1.23	.82	.86	.94	
3					2.22	3.05	2.22	1.19	.83	.87	.94	
4				1.56	2.42	3.17	2.05	1.13	.83	.87	.93	
5				1.56	2.27	3.25	1.89	1.14	.82	.87	.94	
6				1.56	2.32	3.27	1.91	1.14	.82	.87	1.08	
7				1.31	2.43	3.05	1.90	1.00	.82	.93	1.09	
8				1.21	2.47	3.05	1.91	1.03	.83		1.08	
9				1.31	2.48	3.02	1.90	1.04	.83		1.08	
10				1.27	2.65	3.17	1.85	1.00	.82		1.11	
11				1.27	2.75	3.11	1.76	.98	.82		1.09	
12				1.41	2.79	3.16	1.69	.95	.82	.89	1.10	
13				1.51	2.80	3.14	1.69	.90	.82	.93	1.10	
14				1.61	2.95	3.14	1.76	.93	.83	.93	1.10	
15				1.71	3.01	3.19	1.61	.90	.83	.91	1.10	
16				1.91	3.07	3.10	1.60	.87	.83	.93	1.14	
17				1.81	3.14	3.05	1.54	.86	.83	.92	1.10	
18				1.81	3.14	3.01	1.46	.85	.83	.91	1.75	
19				1.86	3.19	3.03	1.41	.85	.82	.93	1.15	
20				1.86	3.19	2.99	1.38	.85	.84	.93	1.18	
21				1.91	3.02	2.94	1.37	.84	.85	.94	1.17	
22				1.86	3.27	2.76	1.37	.84	.88	.96	1.16	
23				1.86	3.19	2.64	1.39	.84	.89	.97		
24				2.26	3.15	2.51	1.33	.84	.85	.97		
25				2.21	3.05	2.32	1.28	.84	.84	.98		
26				2.41	2.90	2.21	1.31	.84	.85	.99		
27				2.41	2.70	2.30	1.29	.84	.84	.98		
28				2.51	2.52	2.20	1.25	.84	.87	.99		
29				2.46	2.49	2.53	1.46	.83	.86	1.00		
30				2.36	2.39	2.39	1.50	.83	.86	.99		
31					2.20		1.31	.83		.97		
1903.												
1				1.76	2.95	2.50	2.95	1.47	.85	1.80	1.86	2.14
2				1.70	2.80	2.52	2.95	1.47	.82	1.72	1.86	2.00
3				1.80	2.83	2.51	2.95	1.40	.80	1.69	1.86	1.81
4				2.15	2.81	2.56	2.95	1.40	.80	1.71	1.85	1.94
5				2.44	2.71	2.65	2.80	1.40	.82	1.67	1.89	2.12
6				2.30	2.71	2.90	2.70	1.40	.72	1.61	1.87	2.30
7				2.21	2.68	3.05	2.72	1.30	.77	1.65	1.90	2.01
8				2.23	2.63	3.16	2.65	1.30	.77	1.70	1.86	1.91
9				2.15	2.59	3.36	2.60	1.25	.95	1.75	1.91	1.80
10				2.14	2.60	3.39	2.35	1.25	.95	1.80	1.89	1.67
11				2.14	2.58	3.40	2.32	1.35	.72	1.76	1.81	1.60
12				2.15	2.60	3.44	2.32	1.25	.82	1.77	2.02	1.45
13				2.25	2.65	3.60	2.25	1.25	.81	1.74	2.01	1.43
14				2.25	2.69	3.50	2.15	1.30	1.35	1.76	2.10	1.50
15				2.26	2.56	3.50	2.10	1.15	1.50	1.76	2.07	1.46
16				2.21	2.85	3.46	2.05	1.15	1.60	1.79	2.08	1.47
17				2.30	2.87	3.56	2.05	1.23	1.60	1.80	2.78	1.46
18				2.34	2.90	3.65	2.00	1.18	1.65	1.84	2.67	1.65
19				2.33	3.02	3.71	1.87	1.05	1.65	1.87	2.18	1.70
20				2.35	3.11	3.65	1.80	.95	1.66	1.82	1.65	1.66
21				2.34	3.20	3.78	1.70	.92	1.65	1.81	2.00	1.76
22				2.35	3.24	3.91	1.63	.90	1.65	1.85	2.30	1.85
23				2.36	3.17	3.80	1.67	.72	1.68	1.85	2.00	1.81
24				2.46	2.97	3.75	1.82	1.10	1.70	1.80	2.01	1.71
25				2.40	2.95	3.70	1.87	1.20	1.70	1.80	1.92	1.91
26				2.41	2.90	3.61	1.75	1.10	1.75	1.80	2.04	1.82
27				2.04	2.80	3.42	1.60	.87	1.74	1.81	2.08	2.00
28				2.70	2.84	3.30	1.55	.85	1.80	1.82	2.03	1.82
29				2.83	2.76	3.31	1.50	.85	1.77	1.82	2.10	1.79
30				2.93	2.60	3.25	1.50	.82	1.72	1.88	2.16	1.80
31			1.76				1.50	.87		1.89		2.00
1904.												
1	2.08			2.22	2.75	4.30	3.30	2.12	1.97	1.75	1.87	1.81
2	2.00	2.50		2.15	2.80	4.50	3.28	2.16	1.93	1.72	1.86	1.83
3	1.95	2.25		2.14	2.84	4.40	3.40	2.13	1.90	1.70	1.85	1.86
4	1.85	2.20		2.32	2.94	4.60	3.07	2.12	1.95	1.73	1.80	1.78
5	2.03	2.22		2.30	3.70	4.35	3.00	2.10	1.93	1.75	1.86	1.71

Mean daily gage height, in feet, of North Platte River at Mitchell, 1901–1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.												
6	1.97	2.23	2.53	2.27	3.90	4.50	3.15	2.11	1.95	1.70	1.87	1.73
7	1.85	2.20	2.45	2.25	3.84	4.70	3.23	2.15	1.97	1.75	1.88	1.72
8	1.90	2.15	2.60	2.27	3.70	4.80	3.20	2.09	1.93	1.77	1.89	1.71
9	2.12	2.17	2.55	2.18	3.58	4.75	3.15	2.11	1.90	1.70	1.86	1.72
10	1.87	2.25	2.57	2.17	3.49	4.73	3.10	2.11	1.95	1.75	1.88	1.74
11	2.10	2.20	2.55	2.18	3.45	4.60	3.05	2.08	1.85	1.73	1.89	1.75
12	2.00	2.23	2.50	2.15	3.40	4.40	3.00	2.02	1.87	1.76	1.98	1.77
13	2.15	2.19	2.47	2.20	3.37	4.55	2.90	2.00	1.85	1.70	1.97	1.80
14	2.12	.....	2.45	2.25	3.35	4.00	2.85	2.05	1.90	1.75	1.96	1.78
15	2.25	.....	2.43	2.19	3.33	4.35	2.75	2.07	1.92	1.70	1.98	1.76
16	2.15	.....	2.45	2.20	3.37	4.20	2.63	2.00	1.95	1.73	1.97	1.73
17	2.30	.....	2.47	2.18	3.45	4.30	2.60	2.01	1.90	1.75	1.95	2.30
18	2.37	.....	2.46	2.13	3.47	4.40	2.59	2.05	1.89	1.72	1.93	2.30
19	2.35	.....	2.47	2.10	3.48	4.30	2.58	1.95	1.92	2.05	1.94	2.30
20	2.38	.....	2.45	2.40	3.45	4.50	2.55	2.00	1.85	2.00	1.95	2.00
21	2.40	.....	2.47	2.60	3.72	4.40	2.53	2.03	1.87	1.95	1.97	1.90
22	2.45	.....	2.43	2.58	3.67	4.15	2.50	1.95	1.83	1.92	1.89	1.80
23	2.45	.....	2.42	2.60	4.90	4.20	2.48	1.97	1.85	1.90	1.87	1.77
24	.....	.....	2.38	2.65	4.90	4.35	2.48	1.90	1.87	1.95	1.86	1.76
25	.....	.....	2.30	2.71	4.00	4.50	2.45	1.95	1.83	1.93	1.85	.....
26	.....	.....	2.34	2.75	4.30	4.65	2.42	1.93	1.80	1.95	1.87	.....
27	.....	.....	2.32	2.80	4.20	4.57	2.45	1.94	1.82	1.90	1.88	.....
28	.....	.....	2.35	2.79	4.50	4.40	2.40	1.92	1.79	1.88	1.84	.....
29	.....	.....	2.33	2.81	4.10	4.30	2.35	1.93	1.75	1.92	1.85	.....
30	.....	.....	2.30	2.82	4.80	3.90	2.30	1.90	1.77	1.92	1.83	.....
31	.....	.....	2.32	.....	4.50	.....	2.26	1.94	.....	1.87	.....	.....
1905.												
1	1.87	1.67	2.72	2.5	4.1	5.0	4.1	2.7	2.1	1.9	.....	.....
2	1.79	.....	2.65	2.6	4.1	4.9	4.1	2.6	2.0	1.9	.....	.....
3	1.77	.....	2.4	2.6	4.2	4.8	4.1	2.7	2.0	1.9	.....	.....
4	1.8	.....	2.37	2.55	4.3	4.8	3.9	2.7	2.0	1.9	.....	.....
5	1.81	.....	2.35	2.5	4.4	4.8	3.8	2.6	2.0	1.9	.....	.....
6	1.76	.....	2.34	2.5	4.3	4.8	3.7	2.6	1.9	1.9	.....	.....
7	1.77	.....	2.32	2.5	4.4	4.8	3.6	2.6	1.9	1.9	.....	.....
8	1.78	.....	2.3	2.5	4.5	4.9	3.6	2.5	2.0	1.9	.....	.....
9	1.75	.....	2.34	2.5	4.4	5.1	3.5	2.5	2.0	1.9	.....	.....
10	1.74	.....	2.35	2.5	4.4	5.0	3.4	2.5	1.95	1.9	.....	.....
11	1.65	.....	2.34	2.6	4.3	5.0	3.2	2.5	1.9	1.9	.....	.....
12	1.64	.....	2.25	2.7	4.2	5.0	3.2	2.5	1.9	1.9	.....	.....
13	1.64	.....	2.3	2.7	4.2	5.2	3.1	2.65	1.9	1.9	.....	.....
14	1.65	.....	2.27	2.8	4.15	5.2	3.0	2.8	1.9	2.0	.....	.....
15	1.66	.....	2.35	2.8	4.1	5.0	2.9	2.6	1.9	2.0	.....	.....
16	1.76	.....	2.38	2.9	4.1	4.9	2.85	2.5	1.9	2.0	.....	.....
17	1.71	.....	2.41	3.0	4.1	4.8	2.8	2.4	1.9	1.9	.....	.....
18	1.82	.....	2.35	3.1	4.0	4.8	2.7	2.3	1.9	1.9	.....	.....
19	1.86	.....	2.4	3.1	3.9	4.8	2.6	2.3	1.9	1.9	.....	.....
20	1.88	.....	2.35	3.1	3.9	4.7	2.6	2.25	1.9	2.0	.....	.....
21	1.95	.....	2.4	3.1	4.0	4.7	2.5	2.2	1.9	2.0	.....	.....
22	2.0	2.1	2.45	3.3	4.1	4.6	2.5	2.3	1.9	2.0	.....	.....
23	2.05	2.15	2.5	3.4	4.2	4.4	2.55	2.3	1.9	2.0	.....	.....
24	2.1	2.25	2.45	3.5	4.9	4.3	2.6	2.2	1.9	2.0	.....	.....
25	1.87	2.3	2.35	3.6	4.7	4.25	2.6	2.2	1.9	2.0	.....	.....
26	2.07	2.53	2.42	4.1	4.6	4.2	2.5	2.2	1.9	2.0	.....	.....
27	2.09	2.55	2.4	4.2	4.6	4.1	2.7	2.15	1.9	2.0	.....	.....
28	2.01	2.6	2.36	4.1	4.7	4.0	2.8	2.1	1.9	2.0	.....	.....
29	1.8	.....	2.42	4.3	4.8	4.0	2.8	2.0	1.9	2.05	.....	.....
30	1.72	.....	2.45	4.2	4.9	4.0	2.75	2.0	1.9	2.1	.....	.....
31	1.69	.....	2.42	.....	4.9	.....	2.7	2.0	.....	2.1	.....	.....
1906.												
1	.....	.....	.....	.....	3.80	5.10	.....	2.80	2.50	2.50	2.70	.....
2	.....	.....	.....	.....	3.70	5.30	3.70	2.80	.....	2.50	2.70	.....
3	.....	.....	.....	.....	3.60	.....	3.60	2.80	2.40	2.50	2.80	.....
4	.....	.....	.....	.....	3.50	5.00	3.50	2.80	2.40	2.50	.....	.....
5	.....	.....	.....	.....	3.60	4.80	3.40	.....	2.40	2.50	2.80	.....
6	.....	.....	.....	3.60	.....	4.70	3.40	2.70	2.40	2.50	2.80	.....
7	.....	.....	.....	3.50	3.50	4.60	3.30	2.70	2.40	.....	2.80	.....
8	.....	.....	.....	.....	3.50	4.40	.....	2.70	2.50	2.50	2.80	.....
9	.....	.....	.....	3.40	3.50	4.40	3.20	2.90	.....	2.50	2.70	.....
10	.....	.....	.....	3.30	3.50	.....	3.20	2.80	2.40	2.40	2.70	.....

Mean daily gage height, in feet, of North Platte River at Mitchell, 1901–1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906.												
11				3.30	3.60	4.50	3.20	2.70	2.40	2.40		
12				3.30	3.60	4.40	3.20		2.40	2.40	2.70	
13				3.40		4.20	3.30	2.70	2.50	2.40	2.70	
14				3.50	3.70	4.00	3.30	2.70	2.60		2.80	
15				3.80	3.80	3.90		2.60	2.60	2.40	2.90	
16				3.80	3.90	4.00	3.30	2.60		2.40	2.80	
17				3.80	4.00		3.40	2.50	2.60	2.40	2.80	
18				3.60	4.00	4.50	3.50	2.50	2.50	2.40		
19				3.60	3.90	4.50	3.40		2.50	2.50		
20				3.50		4.40	3.30	2.40	2.50	2.50		
21				3.50	3.90	4.40	3.20	2.40	2.50			
22					4.00	4.20		2.50	2.40	2.50		
23				3.50	4.10		3.20	2.70		2.50		
24				3.70	4.20	4.10	3.10	2.80	2.50	2.60		
25				3.60	4.20	4.20	3.10	2.90	2.60	3.00		
26				3.60	4.40		3.00		2.50	2.70	2.60	
27				3.60		4.00	3.00	2.90	2.40	2.60	2.60	
28				3.80	4.70	4.00	3.00	2.90	2.40		2.50	
29					5.20	4.20		2.80	2.40	2.60	2.40	
30				3.90	5.30	4.10	2.90	2.70		2.60	2.40	
31					5.20		2.80	2.60		2.60		

Mean daily discharge, in second-feet, of North Platte River at Mitchell, 1901–1906.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Day.	June.	July.	Aug.	Sept.	Oct.	Nov.
1901.							1901.						
1		4,530		210	298	454	17	8,900	1,263	398	320	443	
2		4,114		210	287	455	18	9,920	1,263	386	298	444	
3	10,521	3,922	1,038	227	287		19	9,400	1,048	409	298	445	
4		3,555		218	298		10	8,850	1,217	409	340	481	
5		3,350		420	287		21	8,478		420	320	455	
6		3,288		375	298		22	7,987		363	330	455	
7		3,102		398	287		23	6,510		375	330	455	
8		2,818		398	276		24	5,838		351	341	455	
9	9,400	2,406		363	266		25	5,264		319	313	454	
10	8,405	2,126		375	276		26	5,075		309	308	454	576
11	7,695	1,768		422	302		27	4,629		303	330	454	
12	7,695	1,650	566	375	235		28	4,595		245	287	454	
13	7,015	1,506	455	330	352		29	4,562		245	287	438	
14	7,015	1,506	398	320	432		30	4,560		320	308	454	
15	12,120	1,326	398	320	520		31			218		432	
16	8,405	1,294	432	308	443								

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.											
1				2,703	4,695	2,910	533	34	130	397	
2				2,958	5,110	3,777	559	30	130	386	
3				2,649	5,627	2,635	507	32	140	386	
4			917	3,126	6,145	2,209	432	34	145	374	
5			932	2,795	6,510	1,853	443	34		386	
6			947	2,910	6,877	1,853	455	34		559	
7			612	3,203	5,590	1,798	298	37		572	
8			494	3,335	5,590	1,779	329	44		559	
9			639	3,363	5,477	1,724	329	44		559	
10			598	3,864	6,100	1,596	277	44		598	
11			612	4,186	5,839	1,406	245	48		572	
12			818	4,039	6,027	1,263	209	48	201	585	
13			976	4,371	5,926	1,232	158	54	245	585	
14			1,140	4,896	5,839	1,326	175	58	245	585	
15			1,310	5,110	5,969	1,080	145	58	235	585	
16			1,668	5,365	5,515	1,050	124	62	266	776	
17			1,506	5,665	5,254	961	114	66	256	585	
18			1,524	5,665	5,038	846	104	66	256	652	
19			1,632	5,926	5,038	776	102	66	266	652	
20			1,650	5,969	4,896	734	102	79	287	693	

Mean daily discharge, in second-feet, of North Platte River at Mitchell, 1901–1906—Cont'd.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.											
21			1,761	5,290	4,729	720	94	89	298	679	
22			1,687	6,373	4,186	720	89	109	329	666	
23			1,705	6,056	3,835	748	84	114	351		
24			2,545	5,882	3,470	666	79	99	363		
25			2,455	5,515	2,982	598	74	99	386		
26			2,934	5,002	2,934	639	70	104	443		
27			2,958	4,371	2,958	612	66	104	432		
28			3,229	3,864	2,703	598	62	124	443		
29			3,126	3,777	3,497	860	54	119	455		
30			2,910	3,497	3,102	918	51	124	443		
31				3,006		652	44		420		
1903.											
1			1,710	5,070	3,250	5,310	900	190	1,500	1,600	
2			1,600	4,370	3,250	5,310	900	180	1,300	1,600	
3			1,820	4,600	3,250	5,310	800	180	1,300	1,600	
4			2,670	4,370	3,410	5,310	800	180	1,300	1,600	
5			3,580	3,950	3,760	4,600	800	180	1,200	1,710	
6			3,100	3,950	4,830	4,150	800	165	1,100	1,600	
7			2,810	3,950	5,550	4,150	650	170	1,200	1,710	
8			2,810	3,760	6,050	3,950	720	170	1,300	1,600	
9			2,540	3,580	7,150	3,760	520	220	1,400	1,710	
10			2,540	3,580	7,450	2,950	520	220	1,500	1,710	
11			2,540	3,580	7,450	2,810	650	165	1,400	1,500	
12			2,540	3,580	7,760	2,810	520	180	1,400	1,930	
13			2,670	3,760	8,740	2,670	520	180	1,400	1,930	
14			2,670	3,950	8,080	2,410	580	580	1,400	2,170	
15			2,670	3,410	8,080	2,290	400	900	1,400	2,050	
16			2,540	4,600	7,760	2,170	400	1,100	1,500	2,170	
17			2,810	4,600	8,410	2,170	520	1,100	1,500		
18			2,950	4,830	9,080	2,050	460	1,200	1,600		
19			2,950	5,310	9,430	1,710	300	1,200	1,600		
20			2,950	5,800	9,080	1,600	220	1,200	1,500		
21			2,950	6,310	10,150	1,400	200	1,200	1,500		
22			2,950	6,580	10,870	1,300	200	1,200	1,600		
23			2,810	6,050	10,150	1,300	165	1,300	1,600		
24			3,100	5,070	9,790	1,600	350	1,300	1,500		
25			2,950	5,070	9,430	1,710	460	1,300	1,500		
26			2,950	4,830	9,080	1,500	350	1,400	1,500		
27			2,050	4,370	7,760	1,200	190	1,400	1,500		
28			3,950	4,600	7,150	1,100	190	1,500	1,500		
29			4,600	4,150	7,150	1,000	190	1,400	1,500		
30			5,070	3,580	6,860	1,000	180	1,300	1,710		
31						1,000	190		1,710		
1904.											
1	1,810		950	2,710	9,530	4,905	750	480	210	480	270
2	1,090		850	2,900	10,555	4,905	850	480	150	340	340
3	950		850	3,090	10,040	5,330	850	400	150	340	340
4	950		1,225	3,380	11,080	4,075	750	480	210	270	270
5	1,090	1,985	1,225	6,655	9,785	3,675	750	480	210	340	150
6	950	1,660	1,090	7,580	10,555	4,280	750	480	150	340	210
7	850	2,160	1,090	7,345	11,610	4,695	850	480	210	400	150
8	850	1,985	1,090	6,655	12,150	4,485	750	480	210	400	150
9	1,090	1,985	950	6,205	11,880	4,280	750	400	150	340	150
10	950	1,985	850	5,765	11,880	4,075	750	480	210	400	210
11	1,090	1,810	950	5,550	11,080	3,875	750	340	210	400	210
12	950	1,660	850	5,330	10,040	3,675	570	340	210	570	210
13		1,660	950	5,115	10,820	3,285	570	340	150	480	270
14		1,660	1,090	5,115	11,080	3,090	660	400	210	480	270
15		1,660	950	5,115	9,785	2,710	660	400	150	570	210
16		1,660	950	5,115	9,030	2,340	570	480	210	480	210
17		1,660	950	5,550	9,530	2,160	570	400	210	480	1,225
18		1,660	850	5,550	10,040	2,160	660	400	150	480	1,225
19		1,660	750	5,765	9,530	2,160	480	400	660	480	1,225
20		1,660	1,510	5,550	10,555	1,985	570	340	570	480	570
21		1,660	2,160	6,655	10,040	1,985	660	340	480	480	400
22		1,510	2,160	6,430	8,785	1,810	480	340	400	400	270
23		1,510	2,160	12,700	9,030	1,810	480	340	400	340	210
24		1,225	2,340	12,700		1,810	400	340	480	340	210
25		1,365	2,525	8,055		1,660	480	340	480	340	

Mean daily discharge, in second-feet, of North Platte River at Mitchell, 1901–1906—Cont'd.

Day.	Feb.	Mar.	Apr.	May.	June.	July	Aug.	Sept.	Oct.	Nov.	Dec.
1904.											
26		1,225	2,710	9,530	11,345	1,510	480	270	480	340	
27		1,365	2,900	9,030	10,820	1,660	480	270	400	400	
28		1,365	2,900	10,555	10,040	1,510	400	270	400	340	
29		1,225	2,900	8,540	9,530	1,365	480	210	400	340	
30		1,225	2,900	12,150	7,580	1,225	400	210	400	340	
31				10,555		1,090	480		340		
1905.											
1		2,036	1,480	8,300	15,100	8,300	1,980	670	380		
2		1,850	1,720	8,300	14,300	8,300	1,720	520	380		
3		1,250	1,720	8,900	13,500	8,300	1,980	520	380		
4		1,184	1,600	9,600	13,500	7,150	1,980	520	380		
5		1,140	1,480	10,300	13,500	6,600	1,720	520	380		
6		1,118	1,480	9,600	13,500	6,050	1,720	380	380		
7		1,074	1,480	10,300	13,500	5,500	1,720	380	380		
8		1,030	1,480	11,100	14,300	5,500	1,480	520	380		
9		1,118	1,480	10,300	15,900	5,000	1,480	520	380		
10		1,140	1,480	10,300	15,100	4,520	1,480	450	380		
11		1,118	1,720	9,600	15,100	3,650	1,480	380	380		
12		935	1,980	8,900	15,100	3,650	1,480	380	380		
13		1,030	1,980	8,900	16,800	3,260	1,850	380	380		
14		973	2,260	8,600	16,800	2,900	2,260	380	520		
15		1,140	2,260	8,300	15,100	2,570	1,720	380	520		
16		1,206	2,570	8,300	14,300	2,415	1,480	380	520		
17		1,273	2,900	8,300	13,500	2,260	1,250	380	380		
18		1,140	3,260	7,700	13,500	1,980	1,030	380	380		
19		1,250	3,260	7,150	13,500	1,720	1,030	380	380		
20		1,140	3,260	7,150	12,700	1,720	935	380	520		
21		1,250	3,260	7,700	12,700	1,480	840	380	520		
22		1,365	4,070	8,300	11,900	1,480	1,030	380	520		
23		1,480	4,520	8,900	10,300	1,600	1,030	380	520		
24		1,365	5,000	14,300	9,600	1,720	840	380	520		
25		1,140	5,500	12,700	9,250	1,720	840	380	520		
26		1,296	8,300	11,900	8,900	1,480	840	380	520		
27		1,250	8,900	11,900	8,300	1,980	755	380	520		
28		1,162	8,300	12,700	7,700	2,260	670	380	520		
29		1,296	9,600	13,500	7,700	2,260	520	380	595		
30		1,365	8,900	14,300	7,700	2,120	520	380	670		
31		1,296		14,300		1,980	520		670		
1906.											
1				5,580	14,100	6,110	1,640	940	680	1,160	
2				5,070	15,700	5,070	1,640	845	680	1,160	
3				4,580	14,500	4,580	1,640	750	680	1,400	
4				4,120	13,300	4,120	1,640	680	680	1,400	
5				4,580	11,800	3,680	1,510	680	680	1,400	
6			4,580	4,350	11,100	3,680	1,380	680	600	1,450	
7			4,120	4,120	10,400	3,270	1,380	680	600	1,450	
8			3,900	4,120	9,060	3,080	1,380	860	600	1,450	
9			3,680	4,120	9,060	2,890	1,920	770	600	1,200	
10			3,270	4,120	9,380	2,890	1,640	680	500	1,200	
11			3,270	4,580	9,710	2,890	1,380	680	500	1,220	
12			3,270	4,580	9,060	2,890	1,380	680	500	1,240	
13			3,680	4,820	7,820	3,270	1,380	770	500	1,240	
14			4,120	5,070	6,660	3,270	1,380	960	500	1,500	
15			4,820	5,580	6,110	3,270	1,150	960	500	1,750	
16			5,580	6,110	6,660	3,270	1,150	960	500	1,520	
17			5,580	6,660	8,120	3,680	940	960	510	1,520	
18			5,070	6,660	9,710	4,120	940	770	510	1,300	
19			4,580	6,110	9,710	3,680	845	770	650	1,300	
20			4,120	6,110	9,060	3,270	750	770	650	1,300	
21			4,120	6,110	9,060	2,890	750	770	675	1,300	
22			4,120	6,660	9,060	2,890	940	600	700	1,300	
23			4,120	7,230	7,820	2,890	1,380	640	700	1,300	
24			5,070	7,820	7,520	2,540	1,640	680	860	1,300	
25			4,580	7,820	7,230	2,540	1,920	850	1,820	1,300	
26			4,580	9,060	7,820	2,220	1,920	680	1,070	1,080	
27			4,580	10,000	6,660	2,220	1,920	530	900	1,080	
28			5,580	11,100	6,660	2,220	1,920	530	900	900	
29			5,840	14,900	7,820	2,070	1,640	530	900	720	
30			6,110	15,700	7,230	1,920	1,380	605	900	720	
31				14,900		1,640	1,150		900		

Estimated monthly discharge of North Platte River at Mitchell, 1901–1906.

[Drainage area, 24,400 square miles.]

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
March.								
1904	2,170	1,200	1,632	100,400	0.067	0.08	10	0.78
1905	2,040	935	1,239	76,200	.052	.06	9	.64
April.								
1902	3,230	494	1,603	95,500	.066	.07	5	1.29
1903	5,070	1,600	2,862	170,300	.117	.13	9	1.37
1904	2,980	710	1,511	89,900	.062	.07	8	.91
1905	9,600	1,480	3,573	212,600	.146	.16	5	3.17
1906	6,110	3,270	4,490	223,000	.184	.20	12	1.71
May.								
1902	6,370	2,650	4,346	267,200	.178	.20	11	1.86
1903	6,580	3,410	4,471	274,900	.183	.21	11	1.83
1904	12,700	2,720	6,873	422,600	.281	.32	11	2.78
1905	14,300	7,150	10,010	615,500	.410	.47	16	2.85
1906	15,700	4,120	6,850	421,000	.280	.32	13	2.47
June.								
1901	12,120	4,560	7,514	448,000	.307	.34	13	2.54
1902	6,880	2,700	4,915	242,400	.202	.23	9	2.62
1903	10,870	3,250	7,340	436,800	.300	.34	23	1.45
1904	12,150	7,580	10,270	611,100	.421	.47	17	2.81
1905	16,800	7,700	12,760	759,300	.520	.58	43	1.34
1906	15,700	6,110	9,260	551,000	.379	.42	29	1.46
July.								
1901 [a]	4,530	1,050	2,353	93,300				.80
1902	3,780	598	1,308	80,400	.053	.06	4	1.44
1903	5,310	1,000	2,632	161,800	.107	.12	6	2.02
1904	5,330	1,090	2,875	176,800	.118	.14	9	1.52
1905	8,300	1,480	3,594	221,000	.147	.17	9	1.94
1906	6,110	1,640	3,190	196,000	.131	.15	11	1.40
August.								
1901 [b]	566	218	398	16,300				1.07
1902	559	44	207	12,700	.008	.01	1	.90
1903	900	165	472	29,000	.019	.02	1	1.56
1904	842	400	594	36,500	.024	.03	5	.63
1905	2,260	520	1,296	79,700	.053	.06	5	1.10
1906	1,920	750	1,410	86,700	.058	.07	5	1.48
September.								
1901	422	210	322	19,200	.013	.01	1	.83
1902	124	30	69	4,100	.003	.003	0.1	1.96
1903	1,500	165	765	45,500	.031	.03	2	1.66
1904	498	225	382	22,700	.016	.02	2	.93
1905	670	380	420	25,000	.017	.02	2	1.22
1906	960	530	742	44,200	.030	.03	1	1.94
October.								
1901	520	235	384	23,600	.016	.02	2	.92
1902	455	130	299	18,400	.012	.01	1	.85
1903	1,710	1,100	1,449	89,100	.059	.07	13	.52
1904	625	170	307	18,900	.013	.02	2	.86
1905	670	380	460	28,300	.019	.02	3	.79
1906	1,820	500	708	43,500	.029	.03	2	1.88
November.								
1902 [c]	776	374	563	24,600				.14
1903 [d]	2,170	1,500	1,762	55,900				.26
1904	512	280	398	23,700	.016	.02	100	.02
1906	1,750	720	1,270	75,600	.052	.06	7	.88

[a] July 1 to 20. [b] August 12 to 31. [c] November 1 to 22. [d] November 1 to 16.

72607—IRR 230—09——5

NORTH PLATTE RIVER AT GERING.

Observations were begun at Gering May 29, 1897, and were continued during the open seasons until 1901, when the Mitchell station was established. The station is 1 mile north of Gering and is shown on the Scotts Bluff topographic atlas sheet.

The channel is straight at the section and the bed is composed of shifting sand. The banks are low but seldom overflow.

The gage was on the upstream side of the highway bridge from which the measurements were made, being spiked to a piling near the right bank. The bench mark was a spike in the top of the upstream end of the first cap from the right end of the bridge; elevation, 6.61 feet above zero of the gage.

Discharge measurements of North Platte River at Gering, 1897–1901.

Date.	Hydrographer.	Gage height.	Discharge.
1897.		*Feet.*	*Sec.-ft.*
May 29	O. V. P. Stout	3.28	23,364
September 11	do	.90	500
November 2	do	1.02	661
1898.			
May 13	R. H. Willis	1.50	3,572
June 6	do	2.20	9,307
June 22	do	2.20	8,751
July 2	do	1.70	5,237
November 7	A. B. McCoskey	1.06	593
1899.			
April 10	R. H. Willis	1.48	3,412
April 21	do	2.11	9,140
May 2	do	2.35	10,364
May 16	do	2.10	8,543
May 26	do	2.90	12,325
June 6	do	2.70	13,393
June 14	A. B. McCoskey		16,105
1900.			
April 18	R. H. Willis	1.67	5,251
April 27	do	1.90	7,138
May 11	do	2.16	10,980
June 12	do	2.86	13,706
June 21	do	2.24	9,230
June 28	do	1.80	6,321
July 9	do	1.45	2,874
July 19	do	1.55	3,947
August 1	do	1.15	1,152
August 10	do	1.02	849
August 22	do	.93	529
August 30	do	.84	395
September 11	do	.96	385
September 20	do	.85	356
September 26	A. B. McCoskey		333
October 19	R. H. Willis	.32	486
October 20	do	.35	399
October 30	do	.45	522
November 5	A. B. McCoskey		625
1901.			
June 1	O. V. P. Stout	3.45	10,630

Mean daily gage height, in feet, of North Platte River at Gering, 1897–1900.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Day.	May.	June.	July.	Aug.	Sept.	Oct.
1897.							1897.						
1		3.00	1.80	1.20	1.10	0.80	17			1.30	1.40	0.90	0.95
2		3.00	1.80	1.10	1.10	.80	18			1.40	1.30	.90	.95
3		3.12	1.80	1.10	1.10	.80	19			1.50	1.20	.90	.95
4		3.30	1.70	1.20	1.00	.80	20			1.30	1.20	.90	.95
5		3.35	1.70	1.10	1.00	.80	21			1.30	1.10	.90	.95
6			1.60	1.10	1.00	.80	22			1.30	1.10	.85	.95
7			1.50	1.10	1.00	.80	23			1.30	1.00	.85	.95
8			1.50	1.30	.90	.80	24			1.30	1.00	.85	1.00
9			1.60	1.30	.90	.80	25			1.30	1.00	.85	1.00
10			1.70	1.50	.90	.85	26			1.30	.90	.85	1.00
11			1.50	1.30	.90	.85	27			1.30	.90	.85	.95
12			1.40	1.30	.90	.85	28			1.30	.90	.85	.95
13			1.40	1.30	.90	.90	29			1.30	.90	.80	.95
14			1.30	1.40	.90	.90	30		3.50	1.20	.90	.80	.95
15			1.30	1.40	.90	.90	31		3.30	1.20	.90		
16			1.30	1.40	.90	.90							

Mean daily gage height, in feet, of North Platte River at Gering, 1897–1900—Continued.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1898.								
1	1.10	1.70	2.50	1.80	0.90	0.70	0.70	.....
2	1.10	1.60	2.40	1.70	.90	.70	.70	.....
3	1.10	1.70	2.40	1.60	.90	.70	.70	.....
4	1.10	1.80	2.30	1.50	.80	.70	.70	.....
5	1.10	1.90	2.30	1.45	.80	.60	.70	.....
6	1.20	1.80	2.20	1.50	.80	.60	.75	.....
7	1.20	1.70	2.20	1.40	.90	.70	.75	.....
8	1.20	1.70	2.20	1.30	.80	.70	.75	.....
9	1.20	1.70	2.20	1.30	.80	.80	.75	.....
10	1.20	1.70	2.10	1.30	.80	.70	.75	.....
11	1.20	1.60	2.10	1.30	.80	.70	.80	.....
12	1 20	1.60	2.10	1.30	.70	.70	.80	.....
13	1.30	1.50	2.00	1.30	.70	.70	.80	.....
14	1.30	1.50	2.10	1.40	.70	.70	.80	.....
15	1.30	1.50	2.10	1.30	.70	.70	.80	.....
16	1.30	1.60	2.35	1.30	.70	.70	.80	.....
17	1.40	1.70	2.40	1.30	.80	.70	.90	.....
18	1.40	1.80	2.40	1.30	.80	.70	.90	.....
19	1.40	1.90	2.30	1.30	.80	.70	.90	.....
20	1.50	1.90	2.30	1.30	.70	.70	.90	.....
21	1.70	2.00	2.20	1.20	.80	.70	.90	.....
22	1.80	2.00	2.10	1.10	.80	.70	.90	.....
23	1.80	2.10	2.10	1.10	.80	.70	.90	.....
24	1.80	2.10	2.10	1.10	.80	.70	.90	.....
25	1.80	2.00	2.10	1.10	.70	.70	.95	.....
26	1.80	1.90	2.00	1.10	.70	.70	.95	.....
27	1.80	3.00	2.00	1.00	.70	.70	.90	.....
28	1.90	2.90	2.00	1.00	.70	.70	.90	.....
29	1.90	3.00	1.90	1.00	.70	.70	.90	.....
30	1.90	2.80	1.80	1.00	.70	.70	.90	.....
31	.....	2.70	.....	.95	.70	.....	.90	.....
1899.								
1	.....	2.35	2.70	3.20	1.65	1.05	.93	.....
2	.....	2.37	2.71	3.15	1.70	1.02	.95	.....
3	.....	2.35	2.66	3.10	1.75	1.00	.95	.....
4	.....	2.10	2.61	3.07	1.70	1.02	.96	.....
5	.....	2.00	2.60	3.10	1.58	1.04	.95	.....
6	.....	1.95	2.72	3.05	1.55	1.01	.95	.....
7	.....	1.80	3.10	3.00	1.51	1.01	.96	.....
8	.....	1.75	3.00	2.95	1.47	1.00	.96	.....
9	.....	1.73	2.83	2.87	1.48	1.00	.96	.....
10	1.48	1.70	2.73	2.70	1.53	1.00	.97	.....
11	1.41	1.68	2.69	2.75	1.47	1.00	1.06	.....
12	1.53	1.64	2.68	2.68	1.50	1.00	1.07	.....
13	1.85	1.82	2.80	2.55	1.48	1.00	1.07	.....
14	2.22	1.93	2.90	2.46	1.37	.95	1.06	.....
15	2.42	2.00	3.00	2.45	1.35	.95	1.07	.....
16	2.51	2.25	3.20	2.44	1.43	1.00	1.04	.....
17	2.58	2.40	3.25	2.42	1.40	.98	1.10	.....
18	2.38	2.60	3.15	2.37	1.37	1.00	1.02	.....
19	2.43	2.76	3.00	2.30	1.36	1.00	1.16	.....
20	2.20	2.80	2.95	2.25	1.32	1.06	1.20	.....
21	2.21	2.85	3.00	2.13	1.26	1.06	1.23	.....
22	2.08	2.87	3.05	2.05	1.23	.98	1.25	.....
23	1.92	2.87	3.20	2.00	1.23	1.03	1.27	.....
24	1.90	3.10	3.27	2.00	1.20	1.03	1.23	.....
25	1.88	2.85	3.50	1.95	1.20	.98	1.23	.....
26	1.93	2.65	3.55	1.90	1.10	.98	1.23	.....
27	2.12	2.43	3.50	1.85	1.10	1.00	1.27	.....
28	2.40	2.41	3.30	1.81	1.10	.98	1.30	.....
29	2.39	2.43	3.27	1.77	1.13	.91	1.30	.....
30	2.37	2.52	3.25	1.67	1.10	.90	1.30	.....
31	.....	2.70	.....	1.67	1.07	.....	1.30	.....
1900.								
1	.....	2.25	2.75	1.70	1.00	.78	.48	0.35
2	.....	2.20	2.80	1.70	1.00	.77	.35	.36
3	.....	2.25	2.90	1.71	1.02	.78	.33	.36
4	.....	2.40	2.98	1.70	1.00	.79	.27	.37
5	.....	2.35	2.85	1.60	1.01	.76	.27	.39

Mean daily gage height, in feet, of North Platte River at Gering, 1897–1900—Continued.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1900.								
6		2.35	2.85	1.53	1.00	0.77	0.26	0.40
7		2.20	2.82	1.53	.97	.73	.27	.41
8		2.15	2.80	1.44	.98	.76	.27	.40
9		2.15	2.78	1.44	.95	.75	.27	.42
10		2.05		1.40	.96	.80	.26	1.05
11		2.15		1.30	.95	.85	.25	1.04
12		2.16	2.71	1.21	.93	.87	.23	1.03
13		2.30	2.71	1.10	.90	.90	.24	1.04
14		2.36	2.86	1.12	.90	.90	.24	1.05
15		2.53	2.76	1.29	.86	.90	.23	
16		2.62	2.56	1.21	.90	.85	.24	
17		2.65	2.46	1.30	.90	.80	.24	
18	1.67	2.56	2.29	1.30	.90	.80	.23	
19	1.60	2.50	2.23	1.56	.88	.77	.32	
20	1.55	2.45	2.26	1.42	.88	.75	.31	
21	1.55	2.46	2.19	1.25	.88	.75	.31	
22	1.60	2.49	2.01	1.30	.84	.75	.30	
23	1.85	2.40	1.89	1.22	.82	.75	.30	
24	1.90	2.35	1.89	1.30	.80	.75	.31	
25	1.83	2.31	1.91	1.40	.71	.60	.31	
26	1.80	2.29	1.87	1.21	.73	.62	.32	
27	1.90	2.35	1.81	1.21	.76	.60	.33	
28	2.00	2.50	1.80	1.19	.75	.61	.34	
29	2.00	2.53	1.76	1.01	.74	.55	.34	
30	2.40	2.60	1.70	1.05	.75	.53	.36	
31		2.69		1.05	.75		.37	

Mean daily discharge, in second-feet, of North Platte River at Gering, 1897–1900.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Day.	May.	June.	July.	Aug.	Sept.	Oct.
1897.							1897.						
1		18,700	4,269	1,084	815	455	17		12,650	1,428	1,847	500	550
2		18,700	4,269	815	815	455	18		14,300	1,847	1,428	500	550
3		20,400	4,269	815	815	455	19		14,300	2,340	1,428	500	550
4		24,000	3,552	1,084	620	455	20		12,650	1,428	1,428	500	550
5		25,900	3,552	815	620	455	21		11,400	1,428	815	500	550
6		26,000	2,909	815	620	455	22		7,600	1,428	815	468	550
7		24,000	2,340	815	620	455	23		6,600	1,428	650	468	550
8		20,400	2,340	1,428	500	455	24		6,600	1,428	620	468	620
9		18,700	2,909	1,428	500	455	25		5,650	1,428	620	468	620
10		17,300	3,557	2,340	500	468	26		5,650	1,428	500	468	620
11		14,300	2,340	1,428	500	468	27		5,650	1,428	500	468	550
12		11,400	1,847	1,428	500	468	28		6,600	1,428	500	468	550
13		8,700	1,847	1,428	500	500	29	23,360	5,650	1,428	500	455	550
14		11,400	1,428	1,847	500	500	30	27,900	4,850	1,084	500	455	550
15		14,300	1,428	1,847	550	500	31	24,000		1,084	500		
16		14,300	1,428	1,847	500	500							

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1898.							
1	1,000	4,900	12,150	5,750	350	100	100
2	1,000	4,200	11,150	4,900	350	100	100
3	1,000	4,900	11,150	4,200	350	100	100
4	1,000	5,750	10,100	3,400	200	100	100
5	1,000	6,500	10,100	3,000	200	50	100
6	1,450	5,750	9,200	3,400	200	50	150
7	1,450	4,900	9,200	2,700	350	100	150
8	1,450	4,900	9,200	2,000	200	100	150
9	1,450	4,900	9,200	2,000	200	200	150
10	1,450	4,900	8,250	2,000	200	100	150
11	1,450	4,200	8,250	2,000	200	100	200
12	1,450	4,200	8,250	2,000	100	100	200
13	2,000	3,400	7,400	2,000	100	100	200
14	2,000	3,400	8,250	2,700	100	100	200
15	2,000	3,400	8,250	2,000	100	100	200

Mean daily discharge, in second-feet, of North Platte River at Gering, 1897–1900—Cont'd.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1898.							
16	2,000	4,200	10,600	2,000	100	100	200
17	2,700	4,900	11,150	2,000	200	100	350
18	2,700	5,750	11,150	2,000	200	100	350
19	2,700	6,500	10,100	2,000	200	100	350
20	3,400	6,500	10,100	2,000	100	100	350
21	4,900	7,400	9,200	1,650	200	100	350
22	5,750	7,400	8,250	1,000	200	100	350
23	5,750	8,250	8,250	1,000	200	100	350
24	5,750	8,250	8,250	1,000	200	100	350
25	5,750	7,400	8,250	1,000	100	100	500
26	5,750	6,500	7,400	1,000	100	100	500
27	5,750	18,500	7,400	650	100	100	350
28	6,500	17,100	7,400	650	100	100	350
29	6,500	18,500	6,500	650	100	100	350
30	.....	15,700	5,750	650	100	100	350
31	.....	14,600	.....	.....	100	.....	350
1899.							
1	.....	11,308	11,114	18,085	4,452	1,316	893
2	.....	11,308	11,209	17,250	4,785	1,146	893
3	.....	11,019	10,733	16,541	5,197	1,020	893
4	.....	8,728	10,352	16,085	4,854	1,062	893
5	.....	7,793	10,352	16,200	4,062	1,104	935
6	.....	6,880	11,605	15,514	3,936	935	893
7	.....	6,213	15,741	15,067	3,753	893	893
8	.....	5,843	14,625	14,625	3,507	851	893
9	.....	5,698	12,920	13,869	3,446	815	893
10	3,446	5,408	12,000	12,200	3,997	815	893
11	3,155	5,265	11,700	12,818	3,630	815	1,316
12	3,997	4,991	11,700	12,303	3,690	815	1,316
13	6,441	6,290	13,020	11,209	3,446	775	1,316
14	9,708	7,144	14,187	10,542	2,755	584	1,316
15	11,900	7,709	15,513	10,733	2,543	584	1,316
16	13,125	9,891	17,974	10,923	2,926	737	1,316
17	14,080	11,209	19,190	11,114	2,650	622	1,316
18	12,200	12,921	18,686	11,114	2,489	700	900
19	12,818	14,405	17,490	10,352	2,489	653	1,777
20	10,638	14,295	17,600	9,708	2,329	893	1,770
21	10,828	14,295	17,843	8,552	2,077	893	2,000
22	9,525	13,655	18,208	7,709	2,026	800	2,275
23	8,045	13,023	19,694	7,224	2,275	854	2,275
24	7,877	15,290	20,324	7,144	2,275	803	2,000
25	7,625	12,405	23,002	6,595	2,275	737	2,000
26	7,961	10,447	23,500	6,213	1,730	757	2,000
27	9,525	8,465	22,554	5,843	1,730	893	2,275
28	12,000	8,295	19,820	5,553	1,684	893	2,275
29	11,900	8,550	19,190	5,266	1,777	700	2,275
30	11,605	9,342	18,817	4,582	1,639	737	2,275
31	.....	11,019	.....	4,582	1,454	.....	2,275
1900.							
1	.....	10,475	13,800	5,320	1,157	400	400
2	.....	10,190	14,200	5,120	1,150	400	400
3	.....	10,700	15,200	5,110	1,100	400	400
4	.....	12,380	15,800	5,000	1,100	400	400
5	.....	12,000	14,300	4,200	1,050	400	400
6	.....	12,090	14,200	3,600	1,050	400	400
7	.....	10,600	13,800	3,550	1,000	400	400
8	.....	10,260	13,400	2,960	950	400	400
9	.....	10,390	13,190	2,850	900	400	400
10	.....	9,480	13,000	2,720	849	400	400
11	.....	10,400	12,500	2,200	800	385	400
12	.....	10,400	12,180	1,750	800	375	450
13	.....	11,680	12,380	1,300	750	375	400
14	.....	12,200	14,200	1,400	750	360	450
15	.....	13,800	13,210	2,275	700	360	450
16	.....	14,600	11,400	1,900	700	360	450
17	.....	14,600	10,600	2,390	600	360	450
18	5,300	13,800	9,205	2,430	600	360	475
19	4,750	12,990	8,900	4,000	550	360	486
20	4,400	12,380	9,310	3,190	550	356	399

Mean daily discharge, in second-feet, of North Platte River at Gering, 1897–1900—Cont'd.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1900.							
21	4,465	12,200	8,400	2,200	550	360	400
22	4,770	12,390	7,450	2,390	529	360	400
23	6,600	11,310	6,650	1,950	500	360	425
24	7,000	10,700	6,690	2,280	500	360	425
25	6,510	10,250	6,930	2,790	475	375	425
26	6,390	9,870	6,710	1,700	450	375	450
27	7,190	10,390	6,380	1,690	400	375	450
28	8,100	11,680	6,380	1,500	400	375	475
29	8,190	11,800	5,950	1,200	400	375	475
30	11,900	12,400	5,400	1,200	395	375	500
31	.....	13,210	.....	1,200	.....	.....	522

Estimated monthly discharge of North Platte River at Gering.

[Drainage area, 24,400 square miles.]

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
April.								
1898	6,500	1,000	3,108	184,900	0.127	0.14	13	1.07
1899[a]	14,080	3,150	9,448	394,000	.....	.....	.....	.78
1900[b]	11,900	4,400	6,582	169,700	.....	.....	.....	4.45
May.								
1898	18,500	3,400	7,326	450,500	.300	.35	8	4.37
1899	15,290	4,990	9,649	593,300	.395	.46	15	3.14
1900	14,800	9,480	11,672	717,700	.477	.55	80	.69
June.								
1897	26,000	4,850	13,622	810,600	.558	.62	49	1.26
1898	12,150	5,750	9,002	535,600	.368	.41	25	1.64
1899	23,500	10,350	16,025	953,600	.615	.73	45	1.63
1900	15,800	5,400	10,737	638,900	.439	.49	67	.73
July.								
1897	4,270	1,080	2,140	131,600	.088	.10	7	1.51
1898	5,750	650	2,048	125,900	.084	.10	6	1.73
1899	18,080	4,580	10,823	665,500	.443	.52	35	1.49
1900	5,320	1,200	2,689	165,300	.110	.13	6	2.28
August.								
1897	2,340	500	1,071	65,900	.044	.04	2	1.77
1898	350	100	177	10,900	.007	.01	1	.75
1899	5,200	1,450	2,964	182,200	.121	.14	12	1.17
1900	1,160	395	713	43,800	.029	.03	6	.49
September.								
1897	815	455	537	32,000	.022	.02	4	.45
1898	200	50	100	5,900	.004	.005	1	.42
1899	1,320	584	844	50,200	.035	.04	7	.54
1900	400	356	378	22,500	.015	.02	2	1.30
October.								
1897	620	455	514	31,600	.021	.02	4	.46
1898	500	100	258	15,900	.011	.01	1	.72
1899	2,280	893	1,501	92,300	.061	.07	5	1.33
1900	522	399	431	26,500	.018	.02	4	.55

[a] April 10 to 30.

[b] April 18 to 30.

NORTH PLATTE RIVER AT CAMP CLARKE.

The station at Camp Clarke was established June 27, 1896, and observations were continued until the close of the season in 1900. The station was located at the highway bridge at Camp Clarke, in sec. 22, T. 20 N., R. 51 W., and is shown on the Camp Clarke topographic atlas sheet.

The channel is wide and the water is shallow. The bed is composed of shifting sand, and although the banks are low they are not liable to overflow.

The inclined staff gage was located on the right bank 40 feet upstream from the bridge. A spike in the northeast side of the downstream pile at the north end of the first truss span at the right end of the bridge; elevation, 7.55 feet above the zero of the gage. A marked point on the southeast corner of the window sill at the front of the general store; elevation, 9.74 feet above the zero of the gage.

Discharge measurements of North Platte River at Camp Clarke, 1891–1901.

Date.	Hydrographer.	Gage height.	Discharge.
1891.		*Feet.*	*Sec.-ft.*
May 29	United States Geological Survey.		8,075
1892.			
October 8	do		333
1894.			
July 26	O. V. P. Stout		1,900
1896.			
June 27	do	3.18	3,600
August 10	R. H. Willis	2.41	812
November 21	do	2.70	951
1897.			
September 12	O. V. P. Stout	2.11	551
1898.			
May 6	R. H. Willis	3.17	4,541
May 27	do	2.43	6,170
June 8	do	3.54	7,553
June 17	do	3.61	7,391
June 29	do	3.30	5,170
September 28	do	1.79	150
1899.			
April 11	do	2.57	2,484
April 22	do	3.45	8,462
May 3	do	3.41	7,825
May 17	R. H. Willis	3.52	9,953
May 27	do	3.90	14,335
June 8	do	4.42	15,807
July 29	do	3.09	5,002
August 5	do	2.90	4,893
1900.			
April 19	do	3.28	4,928
April 28	do	3.71	7,146
May 14	do	4.10	11,838
June 13	do	4.27	11,334
June 22	do	3.75	7,695
June 29	do	3.35	4,049
July 11	do	2.74	2,116
July 20	do	3.08	3,654
July 28	do	2.61	1,624
August 11	do	2.20	501
August 24	do	2.05	421
September 12	do	1.96	274
September 21	do	2.08	320
October 3	do	2.08	246
October 20	do	2.10	234
October 31	do	2.18	377
October 31	do	2.26	610
1901.			
June 27	do		5,800
July 10	do		2,900

Mean daily gage height, in feet, of North Platte River at Camp Clarke, 1896–1900.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1896.												
1							3.02	2.56	2.36	2.37	2.45	2.91
2							2.94	2.50	2.45	2.40	2.49	2.97
3							2.87	2.50	2.30	2.37	2.51	3.09
4							2.80	2.48	2.35	2.37	2.52	2.99
5							2.75	2.47	2.33	2.40	2.53	3.01
6							2.68	2.48	2.34	2.39	2.28	2.98
7							2.64	2.48	2.35	2.39	2.45	2.98
8							2.65	2.50	2.38	2.41	2.50	2.95
9							2.64	2.45	2.44	2.55	2.67	2.97
10							2.63	2.41	2.51	2.46	2.60	2.97
11							2.62	2.36	2.45	2.44	2.80	2.96
12							2.50	2.34	2.40	2.45	2.80	2.97
13							2.50	2.32	2.48	2.44	2.80	2.95
14							2.49	2.28	2.38	2.45	2.79	2.95
15							2.50	2.29	2.36	2.45	2.69	2.95
16							2.42	2.23	2.34	2.45	2.60	2.95
17							2.45	2.28	2.33	2.44	2.55	2.95
18							2.78	2.40	2.48	2.43	2.60	2.95
19							2.69	2.35	2.33	2.45	2.37	2.95
20							2.49	2.31	2.41	2.43	2.70	2.95
21							2.51	2.38	2.42	2.45	2.70	2.95
22							2.50	2.46	2.40	2.44	2.87	2.96
23							2.67	.....	2.45	2.41	2.89	2.96
24							2.65	.....	2.50	2.42	2.89	2.96
25							2.58	2.36	2.48	2.42	2.86	2.96
26							2.57	2.34	2.41	2.41	2.86	2.96
27							2.65	2.32	2.47	2.45	2.89	2.96
28							2.48	2.32	2.37	2.45	2.89	2.96
29						3.28	2.59	2.43	2.35	2.44	2.89	2.96
30						3.12	2.80	2.35	2.35	2.54	2.89	2.96
31						3.07	2.75	2.33	.....	2.44	.....	2.94

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1897.											
1	2.91	2.89	2.80	2.85	4.20	4.55	3.35	2.30	2.20	2.03	.....
2	2.90	2.89	2.76	2.82	4.26	4.50	3.30	2.35	2.19	2.02	.....
3	2.90	2.89	2.72	2.81	4.20	4.51	3.15	2.50	2.19	2.05	.....
4	2.85	2.89	2.74	2.78	4.25	4.68	3.10	2.52	2.20	2.04	.....
5	2.85	2.89	2.78	2.74	4.26	4.90	3.03	2.45	2.18	2.05	.....
6	2.80	2.89	2.78	2.68	4.25	5.00	2.99	2.50	2.14	2.06	.....
7	2.80	2.89	2.85	2.75	4.32	4.78	2.91	2.54	2.13	2.06	.....
8	2.80	2.89	2.79	2.84	4.25	4.50	2.91	.....	2.12	2.08	.....
9	2.80	2.89	2.55	2.80	4.35	4.27	3.05	2.61	2.12	2.08	.....
10	2.80	2.89	2.46	2.65	4.30	4.10	3.05	2.79	2.10	2.06	.....
11	2.80	2.89	2.30	2.75	4.50	3.95	2.97	2.79	2.10	2.12	.....
12	2.84	2.89	2.20	2.80	4.46	3.87	2.90	2.65	2.10	2.10	.....
13	2.84	2.89	2.12	2.60	4.40	4.00	2.90	2.68	2.13	2.10	.....
14	2.84	2.83	.....	2.75	4.35	4.03	2.80	2.67	2.12	2.10	.....
15	2.85	2.80	2.57	2.75	4.17	4.10	2.75	2.60	2.15	2.11	.....
16	2.87	2.75	2.59	2.77	4.07	4.03	2.65	2.54	2.15	2.11	.....
17	2.87	2.65	2.57	2.75	3.94	4.05	2.57	2.50	2.16	2.11	.....
18	2.89	2.75	2.52	2.79	4.05	4.10	2.92	2.49	2.14	2.12	.....
19	2.89	2.86	2.45	2.90	4.07	4.08	2.92	2.43	2.17	2.17	.....
20	2.89	2.90	2.40	3.30	4.25	4.08	2.68	2.35	2.15	2.15	.....
21	2.89	2.85	2.40	3.60	4.33	3.89	2.60	2.29	2.13	2.20	.....
22	2.89	2.85	2.42	3.68	4.26	3.89	2.62	.....	2.10	2.21	.....
23	2.89	2.85	2.45	3.95	4.37	3.65	2.60	2.30	2.09	2.19	.....
24	2.89	2.85	2.43	4.28	4.56	3.62	2.65	2.24	2.10	2.18	.....
25	2.89	2.85	2.45	4.28	7.72	3.47	2.58	2.25	2.09	2.19	.....
26	2.89	2.85	2.42	3.95	4.78	3.50	2.52	2.22	2.10	2.21	.....
27	2.89	2.85	2.43	3.88	4.77	3.49	2.57	2.20	2.11	2.22	.....
28	2.89	2.80	2.41	3.80	4.72	3.51	2.52	2.22	2.10	2.20	.....
29	2.89	.....	2.42	3.88	4.74	3.57	2.56	2.22	2.11	2.21	.....
30	2.89	.....	2.45	4.00	4.70	3.40	2.45	2.18	2.06	2.21	.....
31	2.89	.....	2.80	.....	4.67	.....	2.40	2.20	.....	2.21	.....

Mean daily gage height, in feet, of North Platte River at Camp Clarke, 1896–1900—Con.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1898.											
1				2.27	2.91	3.89	3.20	2.33	1.65	1.72	
2				2.27	2.84	3.86	3.05	2.32	1.65	1.80	
3				2.37	2.91	3.69	2.98	2.30	1.60	1.80	
4				2.44	3.07	3.60	2.95	2.23	1.60	1.81	
5				2.45	3.12	3.59	2.95	1.98	1.62	1.80	
6				2.35	3.17	3.49	2.86	2.30	1.62	1.80	
7				2.37	3.17	3.47	2.75	2.31	1.65	1.81	
8				2.35	3.05	3.47	2.72	1.90	1.65	1.81	
9				2.39	3.02	3.34	2.68	1.95	1.65	1.83	
10				2.40	3.00	3.50	2.65	1.90	1.87	1.87	
11				2.42	3.02	3.49	2.60	1.86	1.81	1.89	
12				2.49	2.93	3.45	2.70	1.81	1.80	1.89	
13				2.38	3.02	3.45	2.55	1.80	1.80	1.87	
14				2.40	3.04	3.44	2.50	1.78	1.81	1.87	
15				2.42	2.88	3.54	2.50	1.75	1.80	1.85	
16				2.50	2.90	3.56	2.50	1.80	1.80	1.82	
17				2.44	2.92	3.60	2.50	1.85	1.80	1.80	
18				2.55	2.92	3.65	2.50	1.86	1.80	1.80	
19				2.65	2.96	3.55	2.55	1.85	1.75	1.78	
20				2.72	3.17	3.56	2.55	1.80	1.67	1.75	
21				2.85	3.34	4.59	2.50	1.76	1.70	2.05	
22				2.87	3.38	3.57	2.48	1.78	1.70	2.05	
23				3.00	3.45	3.60	2.52	1.78	1.68	2.06	
24				3.06	2.93	3.59	2.47	1.75	1.65	2.04	
25				2.97	3.40	3.55	2.46	1.75	1.72	2.05	
26				2.97	3.44	3.47	2.45	1.72	1.73	2.07	
27				2.97	4.10	3.40	2.35	1.60	1.73	2.10	
28				2.87	4.40	3.34	2.33	1.68	1.79	2.09	
29				2.93	4.35	3.29	2.33	1.68	1.65	2.08	
30				2.96	4.11	3.25	2.35	1.68	1.65	2.07	
31					3.94		2.32	1.66		2.10	
1899.											
1					3.68	4.12	4.81	2.88	2.28	2.28	
2					3.73	4.18	4.83	2.98	2.22	2.27	
3					3.30	4.12	4.85	3.10	2.06	2.23	
4					3.13	4.10	4.88	3.03	2.03	2.22	
5				2.55	3.34	4.09	4.80	2.88	2.11	2.21	
6				2.60	3.30	4.22	4.87	2.88	2.16	2.19	
7				2.62	2.80	4.40	4.83	2.90	2.00	2.30	
8				2.67	2.80	4.35	4.82	2.84	2.10	2.20	
9				2.68	2.74	4.25	4.70	2.75	2.12	2.28	
10				2.58	2.80	4.21	4.50	2.85	2.16	2.25	
11				2.55	2.73	4.02	4.45	2.95	2.11	2.28	
12				2.54	2.87	3.97	4.40	2.91	2.02	2.22	
13				2.86	2.99	4.02	4.25	3.08	2.03	2.29	
14				3.26	3.02	4.08	4.14	2.81	2.15	2.28	
15				3.76	3.19	4.22	4.20	2.74	2.13	2.34	
16				3.70	3.40	4.45		2.84	2.15	2.25	
17				3.58	3.61	4.48		2.82	2.17	2.30	
18				3.58	3.74	4.25		2.77	2.18	2.25	
19				3.60	3.87	4.10	4.00	2.70	2.21	2.22	
20				3.65	4.06		3.93	2.68	2.23	2.25	
21				3.50	4.19		3.80	2.60	2.21	2.40	
22				3.43	4.32	4.80	3.75	2.62	2.19		
23				3.15	4.23	4.95	3.65	2.58	2.22		
24				3.08	4.19	5.08	3.50	2.55	2.40		
25				3.05	4.30	5.30	3.48	2.58	2.30		
26				3.05	4.03	5.35	3.32	2.48	2.23		
27				3.20	3.85	5.20	3.20	2.47	2.20		
28				3.55	3.75	5.00	3.20	2.48	2.30		
29				3.65	3.80	4.85	3.07	2.47	2.22		
30				3.75	3.92	4.85	2.93	2.35	2.25		
31					4.03		3.04	2.34			
1900.											
1					4.10	4.29	3.31	2.25	1.98	2.10	2.23
2					3.85	4.31	3.27	2.33	1.92	2.05	2.23
3					3.85	4.45	3.21	2.30	1.95	2.09	2.22
4					4.05	4.49	3.15	2.38	1.96	2.08	2.24
5											

Mean daily gage height, in feet, of North Platte River at Camp Clarke, 1896–1900—Con.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1900.											
6					3.98	4.52	2.95	2.24	1.97	2.15	2.25
7					3.89	4.48	2.91	2.26	1.98	2.11	2.26
8				2.90	3.92	4.43	2.71	2.20	1.93	2.10	2.28
9				3.03	3.84	4.48	2.70	2.20	2.03	2.10	2.30
10				3.23	3.94	4.42	2.73	2.20	2.08	2.08	2.31
11				3.20	3.92	4.34	2.71	2.16	2.10	2.09	
12				3.27	3.99	4.38	2.62	2.15	2.09	2.11	
13				3.16	4.02	4.27	2.62	2.15	1.96	2.14	
14				3.28	4.10	4.25	2.62	2.15	1.98	2.16	
15				3.42	4.19	4.28	2.74	2.11	2.05	2.18	
16				3.25	4.27	4.17	2.72	2.11	2.02	2.15	
17				3.20	4.34	4.10	2.62	2.10	2.05	2.15	
18				3.30	4.23	3.90	2.73	2.07	2.07	2.16	
19				3.24	4.12	3.89	2.68	2.05	2.04	2.18	
20				3.22	4.05	3.84	3.05	2.07	2.01	2.19	
21				3.21	4.07	3.81	2.83	2.05	2.03	2.20	
22				3.26	4.09	3.75	2.77	2.03	2.02	2.21	
23				3.57	4.05	3.51	2.78	2.06	2.01	2.20	
24				3.57	3.91	3.52	2.83	2.03	2.15	2.20	
25				3.59	3.90	3.48	2.62	2.01	2.19	2.21	
26				3.48	3.82	3.43	2.70	2.00	2.20	2.21	
27				3.57	3.78	3.39	2.59	1.90	2.15	2.22	
28				3.71	3.91	3.42	2.59	1.90	2.15	2.21	
29				3.89	4.01	3.33	2.50	1.93	2.14	2.23	
30				3.79	4.11	3.31	2.40	1.95	2.10	2.25	
31					4.15		2.32	1.99		2.25	

Mean daily discharge, in second-feet, of North Platte River at Camp Clarke, 1896–1900.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Day.	June.	July.	Aug.	Sept.	Oct.	Nov.
1896.							1896.						
1		2,886	1,316	854	875	1,046	17		1,046	706	796	1,023	
2		2,552	1,160	1,056	932	1,137	18		1,977	932	1,114	1,000	
3		2,295	1,160	738	875	1,137	19		1,685	835	796	1,046	
4		2,042	1,114	835	875	1,186	20		1,137	758	954	1,000	
5		1,878	1,092	796	932	1,212	21		1,186	895	977	1,046	931
6		1,655	1,114	816	914	1,338	22		1,160	1,069	932	1,023	
7		1,537	1,114	835	914	706	23		1,226		1,046	954	
8		1,566	1,160	895	954	1,046	24		1,566		1,160	977	
9		1,537	1,046	1,023	1,290	1,160	25		1,368	854	1,114	977	
10		1,508	954	1,186	1,069		26		1,342	816	954	954	
11		1,478	854	1,046	1,023		27	3,600	1,566	777	1,092	1,046	
12		1,160	816	932	1,046		28	4,100	1,114	777	875	1,046	
13		1,160	777	1,114	1,023		29	3,324	1,394	1,000	835	1,023	
14		1,137	706	895	1,046		30	3,102		835	835	1,264	
15		1,137	722	854	1,046		31		1,960	796		1,023	
16		977	628	816	1,046								

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1897.							
1	2,200	7,960	9,250	4,300	740	580	380
2	2,110	8,390	9,250	4,195	835	565	370
3	2,050	7,960	9,250	5,810	1,160	565	400
4	1,950	7,960	10,100	3,250	1,210	580	400
5	1,850	8,390	11,400	2,950	1,040	550	400
6	1,650	7,960	12,000	2,760	1,160	500	410
7	1,850	8,390	10,500	2,440	1,260	490	410
8	2,150	7,960	9,250	2,440		475	430
9	2,050	8,390	8,390	3,000	1,400	475	430
10	1,550	8,390	7,530	3,000	2,000	450	410
11	1,850	9,250	6,670	2,700	2,000	459	475
12	2,050	9,250	6,670	2,400	1,560	450	
13	1,420	8,820	7,100	2,400	1,650	490	465
14	1,850	8,390	7,100	2,040	1,620	475	450
15	1,850	7,960	7,530	1,850	1,420	515	450

Mean daily discharge, in second-feet, of North Platte River at Camp Clarke, etc.—Cont'd.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1897.							
16	1,900	7,530	7,100	1,560	1,270	515	465
17	1,850	6,670	7,100	1,350	1,160	530	465
18	2,000	7,100	7,530	1,710	1,135	500	475
19	2,400	7,100	7,530	2,600	1,000	540	465
20	4,195	7,960	7,530	1,650	835	515	515
21	5,380	8,390	6,670	1,420	720	490	580
22	5,810	7,960	6,670	1,480	.....	450	600
23	6,670	8,000	5,380	1,420	740	440	565
24	8,390	9,000	5,380	1,560	645	450	555
25	8,390	10,100	4,950	1,360	660	440	565
26	6,670	10,500	4,950	1,210	610	450	600
27	6,670	10,500	4,950	1,350	580	465	610
28	6,240	10,100	4,950	1,210	610	450	580
29	6,670	10,100	5,780	1,310	610	465	600
30	7,100	10,100	4,520	1,440	550	410	600
31	.....	10,100	.....	930	580	.....	600
1898.							
1	675	2,600	10,600	4,200	800	80	110
2	675	2,350	10,300	3,350	780	80	150
3	900	2,600	8,500	2,960	725	60	150
4	1,050	2,400	7,600	2,800	600	60	160
5	1,050	3,700	7,550	2,800	300	65	150
6	830	4,000	6,700	2,400	725	65	150
7	900	4,000	6,500	2,050	750	80	160
8	830	3,350	5,900	1,900	230	80	160
9	925	3,150	5,300	1,760	275	80	190
10	950	3,050	6,900	1,650	230	200	200
11	1,000	3,150	6,700	1,550	200	160	220
12	1,175	2,700	6,300	1,800	160	150	220
13	900	3,150	6,300	1,350	150	150	200
14	950	3,300	6,200	1,200	130	160	200
15	1,000	2,500	7,200	1,200	125	150	190
16	1,200	2,600	7,400	1,200	190	150	165
17	1,250	2,650	7,600	1,200	150	150	150
18	1,350	2,650	8,100	1,200	200	150	150
19	1,650	2,800	7,300	1,350	190	125	130
20	1,900	4,000	7,400	1,350	150	90	125
21	2,400	5,300	7,500	1,200	125	105	365
22	2,400	5,700	7,400	1,150	130	105	365
23	3,050	6,300	7,500	1,260	130	95	375
24	3,400	6,100	7,550	1,100	125	80	350
25	2,900	5,900	7,300	1,075	125	110	365
26	2,900	6,200	6,500	1,050	110	115	390
27	2,900	13,300	5,900	850	60	115	425
28	2,450	17,000	5,300	800	95	140	420
29	2,700	17,000	4,800	800	95	80	410
30	2,800	13,400	4,550	850	95	80	390
31	.....	11,300	.....	780	90	.....	425
1899.							
1	.....	10,150	14,713	20,125	3,841	1,077	1,329
2	.....	10,588	14,925	20,125	4,500	1,025	1,300
3	.....	7,145	13,895	20,250	5,335	725	1,217
4	.....	6,037	13,400	20,500	4,903	725	1,189
5	2,648	7,505	12,805	19,410	4,057	927	1,161
6	2,866	7,290	13,793	20,125	3,950	1,049	1,105
7	3,005	4,111	15,455	19,350	3,841	682	1,456
8	3,235	4,165	14,820	19,169	3,435	903	1,161
9	3,335	3,841	13,793	17,773	2,775	952	1,392
10	2,866	4,215	13,591	15,350	3,100	1,025	1,329
11	2,734	3,841	11,950	14,610	3,485	903	1,424
12	2,734	4,675	11,575	13,790	3,235	703	1,245
13	4,384	5,455	12,330	12,235	4,111	725	1,487
14	7,000	5,645	13,200	10,850	2,819	1,000	1,456
15	11,030	6,855	15,030	11,760	2,519	952	1,646
16	10,500	8,500	17,885	.....	3,005	1,000	1,392
17	9,560	10,413	18,585	.....	2,960	1,077	1,550
18	9,560	11,668	15,665	.....	2,775	1,105	1,392
19	9,810	12,914	13,591	10,065	2,476	1,217	1,300
20	10,040	19,050	.....	9,560	2,391	1,273	1,392

Mean daily discharge, in second-feet, of North Platte River at Camp Clarke, etc.—Cont'd.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1899.							
21	9,060	16,220	.....	8,582	2,027	1,245	1,894
22	8,265	17,773	18,234	8,342	2,110	1,189	.....
23	6,443	16,867	18,117	7,730	1,930	1,300	.....
24	5,907	16,430	18,585	6,715	1,823	1,858	.....
25	5,712	17,207	21,619	6,650	1,930	1,487	.....
26	5,647	14,818	23,560	5,712	1,551	1,245	.....
27	6,650	13,000	23,560	5,148	1,519	1,133	.....
28	9,225	12,044	22,900	5,271	1,551	1,392	.....
29	10,065	12,330	20,875	4,500	1,519	1,133	.....
30	10,850	13,200	20,750	3,950	1,189	1,245	.....
31	.....	14,000	.....	4,615	1,189	.....	.....
1900.							
1	.....	10,305	12,110	4,000	625	425	260
2	.....	8,370	12,315	3,960	771	210	200
3	.....	8,450	13,700	3,700	725	260	270
4	.....	10,200	14,050	3,420	900	260	270
5	.....	9,855	14,275	3,550	600	250	230
6	.....	9,820	14,200	2,700	620	270	310
7	.....	9,100	13,700	2,550	630	260	290
8	2,910	9,410	13,200	1,850	550	190	290
9	3,500	8,800	13,650	1,875	550	425	290
10	4,650	9,850	12,845	2,050	575	350	270
11	4,450	9,850	12,010	2,000	450	390	260
12	4,900	10,500	12,350	1,700	450	340	290
13	4,300	10,900	11,260	1,700	450	425	300
14	4,950	11,740	11,250	1,700	480	210	340
15	5,810	12,680	11,640	2,120	400	290	380
16	5,400	13,600	10,550	2,050	420	230	340
17	4,450	14,000	10,050	1,700	420	290	340
18	5,010	12,800	8,410	2,100	400	290	340
19	4,650	11,700	8,510	1,875	390	230	380
20	4,525	10,900	8,210	3,350	420	190	390
21	4,310	11,000	8,120	2,470	400	210	410
22	4,525	11,150	7,675	2,200	400	200	450
23	6,400	10,700	5,900	2,250	450	180	450
24	6,300	9,400	5,820	2,470	400	330	450
25	6,400	9,225	5,400	1,675	390	390	450
26	5,600	8,550	4,990	1,940	380	390	440
27	6,200	8,195	4,510	1,600	230	310	500
28	7,025	9,100	4,510	1,600	230	310	500
29	8,400	10,040	3,960	1,290	260	300	520
30	7,700	10,755	3,960	1,000	290	260	600
31	.....	11,700	.....	775	310	.....	520

Estimated monthly discharge of North Platte River at Camp Clarke, 1896–1900.

[Drainage area, 24,800 square miles.]

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
April.								
1897	8,390	1,570	3,649	217,100	0.147	0.16	13	1.21
1898	3,400	675	1,630	97,000	.066	.08	7	1.07
1899	11,030	2,650	6,659	396,000	.268	.30	38	.78
1900	8,400	2,910	5,328	317,000	.215	.23	5	4.45
May.								
1897	10,500	6,670	8,688	534,200	.350	.40	25	1.59
1898	17,000	2,350	5,403	332,200	.218	.25	6	4.37
1899	19,050	3,840	10,257	630,700	.412	.47	15	3.14
1900	14,000	8,190	10,379	638,200	.416	.48	70	.69
June.								
1897	12,000	4,520	7,491	440,400	.302	.33	28	1.18
1898	10,600	4,550	7,390	439,700	.298	.33	20	1.64
1899	23,560	11,580	16,400	975,900	.660	.73	45	1.63
1900	14,280	3,960	9,771	581,400	.394	.44	60	.73
July.								
1896	2,890	977	1,554	95,500	.062	.07	4	1.88
1897	5,810	930	2,147	132,000	.086	.10	7	1.51
1898	4,200	780	1,617	99,400	.065	.08	5	1.73
1899	20,500	3,950	12,230	752,000	.493	.56	37	1.49
1900	4,000	770	2,227	136,900	.090	.10	4	2.28
August.								
1896	1,320	628	924	56,700	.037	.04	4	.93
1897	2,000	580	1,066	65,500	.043	.05	3	1.77
1898	800	60	266	16,400	.011	.01	1	.75
1899	5,340	1,190	2,834	174,300	.114	.13	11	1.17
1900	900	230	471	29,000	.019	.02	4	.49
September.								
1896	1,190	738	939	55,900	.038	.04	3	1.52
1897	580	400	492	29,300	.020	.02	4	.45
1898	200	60	110	6,500	.004	.004	1	.42
1899	1,860	682	1,076	64,000	.043	.05	9	.54
1900	425	180	289	17,200	.012	.01	1	1.30
October.								
1896	1,290	875	1,008	62,000	.041	.05	9	.56
1897	600	370	484	29,800	.020	.02	4	.56
1898	425	110	245	15,100	.010	.01	1	.72
1899	1,890	1,100	1,372	84,300	.055	.06	5	1.13
1900	600	200	369	22,700	.015	.02	4	.55

NORTH PLATTE RIVER AT BRIDGEPORT.

The Bridgeport station was established May 4, 1902. It is located at the highway bridge on the public road about one-half mile north of Bridgeport, in sec. 28, T. 20 N., R. 50 W., and is shown on the Camp Clarke topographic atlas sheet.

The river is straight both above and below the gaging section for a considerable distance, the channel being narrowed by a dike built as a bridge approach. The bed is composed of shifting sand. There is one channel at ordinary stages, but at low water the stream flows in a large number of small, winding channels. The current is never sluggish, even at low stages. The range of gage heights is about 4 feet.

Discharge measurements are made from the upstream side of the highway bridge, which is supported by pile bents spaced about 20 feet apart.

The gage is of the wire and weight type and is fastened to the upstream hand rail of the bridge. The length of the wire from the index to the end of the weight is 12.80 feet. The gage is referred to three bench marks, as follows: (1) A 6 by 6 inch stone, marked U. S. C. & G. S., in the NE. ¼ sec. 32, T. 20 N., R. 50 W., 130 feet east of the east gate of the stock yards and 300 feet northwest of the northwest corner of the public school building; elevation, 9.94 feet above the zero of the gage. (2) A standard United States Geological Survey bench mark, set in a stone about 50 feet south and a little east of the northeast corner of lot 4, block 2, of Riverside addition to Bridgeport; elevation, 11.32 feet above the zero of the gage. (3) A spike in the top of the upstream end of the cap of the first bent at the right end of the bridge; elevation, 10.14 feet above the zero of the gage.

Discharge measurements of North Platte River at Bridgeport, 1901–1906.

Date.	Hydrographer.	Gage height.	Discharge.
1901.		*Feet.*	*Sec.-ft.*
July 27	R. H. Willis		800
August 28	do		125
1902.			
May 20	do	6.00	5,414
June 3	Frank Dobson	5.80	4,515
June 10	do	5.17	2,049
June 14	do	5.97	5,433
June 21	do	5.71	5,120
July 10	R. H. Willis	5.16	2,084
July 19	Frank Dobson	5.00	787
July 26	do	4.87	615
August 9	do	4.68	190
August 28	R. H. Willis	4.49	37
September 22	do	5.08	634
1903.			
March 31	J. C. Stevens	5.32	1,953
June 5	R. H. Willis	5.67	3,783
June 9	do	6.06	6,174
June 16	do	6.41	8,441
June 19	J. C. Stevens	6.40	10,462
July 4	R. H. Willis	5.77	5,547
July 7	J. C. Stevens	5.65	4,239
July 13	R. H. Willis	5.37	2,492
July 27	do	5.10	918
July 30	J. C. Stevens	4.98	824
August 4	R. H. Willis	4.95	699
August 13	J. C. Stevens	4.90	331
August 18	R. H. Willis	5.12	364
August 29	do	5.05	183
September 7	O. V. P. Stout	5.10	284
October 19	R. H. Willis	5.10	592
1904.			
April 23	J. C. Stevens	5.28	1,236
May 26	do	6.17	7,878
June 9	do	6.56	11,189
July 9	do	5.76	4,486
September 26	R. D. Hubbard	4.69	59
1905.			
March 29	H. C. Gardner	5.10	1,417
May 12	do	6.30	11,040
June 14	do	7.00	17,550
July 12	do	5.65	4,608
July 21	do	5.40	2,367
August 4	do	5.45	2,504
September 13	A. Dobson	4.91	366
1906.			
April 11	F. S. Dobson	5.75	3,448
June 27	Arthur Dobson	6.05	6,511
July 25	do	5.51	2,308
September 2	do	4.74	1,142
October 17	A. R. Wilson	4.81	822
December 7	do	5.55	2,191

Mean daily gage height, in feet, of North Platte River at Bridgeport, 1902–1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1						5.41	5.60	4.85	4.50	4.79	5.02	
2						5.61	5.56	4.75	4.46	4.75	4.95	
3						5.79	5.76	4.80	4.45	4.80	4.98	
4						5.93	5.40	4.78	4.44	4.80	4.88	
5					5.50	5.70	6.04	5.43	4.80	4.40	4.84	4.96
6						5.60	5.99	5.32	4.79	4.40	4.82	5.00
7						5.56	6.10	5.33	4.80	4.40	4.80	
8						5.60	5.93	5.35		4.40	4.82	
9						5.68	5.89	5.27	4.75	4.48	4.85	
10							5.90	5.16	4.72	4.40	4.85	

Mean daily gage height, in feet, of North Platte River at Bridgeport, 1902–1906—Cont'd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
11						5.93	5.19	4.72	4.40	4.91		
12					5.76	5.92	5.10	4.70	4.40	4.95		
13						5.89	5.02	4.67	4.40	4.90		
14					5.80	6.00	5.04	5.05	4.38	4.91		
15					5.89	6.04	5.00	4.75	4.41	4.94		
16					5.86	6.00	5.20	4.68	4.40	4.95		
17					5.91	6.00	5.04	4.70	4.40	4.92		
18					5.99	5.85	5.01	4.65	4.40	4.95		
19					5.95	5.82	5.00	4.62		4.91		
20					6.00	5.82	4.89	4.61	4.46	4.92		
21					6.04	5.75	4.86	4.60				
22					6.10	5.68	4.80	4.59	4.95	4.94		
23					6.04	5.58	4.75	4.60	4.88	4.95		
24					6.04	5.48	4.77	4.62	4.78	4.95		
25					5.96	5.47	4.86	4.52	4.77	4.94		
26					5.86	5.26	4.90	4.52	4.95	4.95		
27					5.65	5.46	4.94	4.56	4.85	4.90		
28					5.56	5.60	4.79	4.60	4.82	4.91	5.00	
29					5.41	5.87	4.76		4.82	4.95		
30					5.45	5.85	4.85		4.79	4.94		
31					5.41		4.90			4.91		
1903.												
1				5.38	6.00	5.70	5.93	5.13	5.10	5.00	5.07	5.32
2				5.36	5.98	5.65	5.86	5.00	5.10	5.05	5.08	5.30
3				5.22	5.95	5.73	5.83	5.08	5.08	5.05	5.10	5.32
4				5.32	5.90	5.85	5.81	5.14	5.10	5.07	5.05	5.30
5				5.58	5.95	5.67	5.85	5.13	5.05	4.95	5.07	5.30
6				5.73	5.93	5.73	5.72	5.09	5.08	5.10	5.10	5.32
7				5.60	5.75	5.92	5.68	5.10	5.10	5.20	5.08	5.50
8				5.60	5.65	6.00	5.63	4.90	5.00	5.15	5.05	5.58
9				5.60	5.77	6.06	5.41	4.95	5.00	5.10	5.05	5.48
10				5.55	5.78	6.20	5.45	5.05	4.98	5.10	5.00	5.40
11				5.52	5.67	6.21	5.54	5.00	4.85	5.22	5.00	5.42
12				5.42	5.60	6.23	5.46	4.95	4.95	5.10	5.02	5.40
13				5.43	5.63	6.30	5.35	5.08	4.90	5.10	5.30	5.38
14				5.41	5.57	6.33	5.29	4.95	5.00	5.15	5.35	
15				5.46	5.70	6.38	5.31	4.90	5.15	5.10	5.30	
16				5.47	5.65	6.41	5.37	5.03	5.12	5.08	5.40	
17				5.50	5.80	6.35	5.45	5.00	4.93	5.05	5.40	
18				5.50	5.83	6.34	5.22	5.10	4.96	5.08	5.40	
19				5.83	5.75	6.39	5.17	5.15	5.00	5.08	5.40	
20				5.53	5.92	6.40	5.30	5.10	5.00	5.05	5.40	
21				5.55	6.05	6.36	5.17	5.08	5.00	5.05	5.35	5.32
22				5.60	6.05	6.33	5.13	5.00	5.10	5.10	5.30	5.35
23				5.58	6.10	6.45	5.12	4.98	5.20	5.12	5.35	5.32
24				5.57	6.15	6.37	4.99	5.30	5.18	5.10	5.37	5.34
25				5.60	5.95	6.37	5.06	5.10	5.18	5.08	5.30	5.30
26				5.80	5.87	6.31	5.27	5.10	5.10	5.05	5.37	5.60
27				5.97	5.85	6.27	5.22	5.20	5.15	5.05	5.35	5.65
28				5.85	5.80	6.16	5.22	5.00	5.07	5.07	5.37	5.75
29				5.85	5.93	6.10	5.11	5.05	5.07	5.08	5.37	5.80
30				5.80	5.90	5.97	5.19	5.08	5.05	5.07	5.37	5.67
31					5.72		5.12	5.10		5.08		5.65
1904.												
1	5.60				5.45	6.46	6.05	4.90	4.82	4.92	5.02	
2	5.55				5.43	6.46	5.92	4.82	4.75	4.85	5.00	
3	5.90				5.52	6.46	6.04	4.75	4.73	4.82	5.02	
4	5.80				5.60	6.55	5.92	4.74	4.72	4.72	5.00	
5	5.35				5.65	6.32	5.74	4.73	4.72	4.75	5.00	
6	5.40				6.05	6.29	5.76	4.79	4.70	4.75	4.95	
7	5.45				6.31	6.48	5.88	4.84	4.70	4.75	4.95	
8	5.42				6.25	6.66	5.76	4.75	4.67	4.75	5.15	
9	5.40				5.88	6.68	5.79	4.75	4.60	4.70	5.20	
10	5.42			5.20	5.82	6.56	5.86	4.72	4.62	4.75	5.00	
11	5.40			5.10	6.01	6.56	5.80	4.70	4.63	4.72	4.90	
12	5.40			5.05	5.74	6.59	5.56	4.68	4.63	4.75	4.92	
13	5.42			5.03	5.72	6.38	5.55	4.64	4.64	4.78	5.05	
14	5.48			5.03	5.72	6.42	5.48	4.64	4.65	4.80	5.20	
15	5.50			5.25	5.82	6.34	5.49	4.65	4.65	4.78	5.17	

Mean daily gage height, in feet, of North Platte River at Bridgeport, 1902–1906—Cont'd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.												
16	5.42			4.98	5.74	6.34	5.40	4.75	4.65	4.80	5.15	
17	5.40			5.15	5.75	6.31	5.32	4.85	4.67	4.75	5.10	
18	5.42			5.05	5.80	6.38	5.31	4.95	4.67	4.80	5.12	
19	5.43			5.03	5.80	6.28	5.30	4.88	4.70	5.35	5.10	
20	5.50			5.05	5.86	6.38	5.25	4.72	4.68	5.30	5.12	
21	5.55			5.07	5.92	6.36	5.22	4.72	4.68	5.10	5.15	
22	5.42			5.35	5.95	6.26	5.21	4.75	4.70	5.05	5.08	
23	5.42			5.20	6.36	6.30	5.25	4.70	4.70	5.00	5.17	
24				5.75	6.58	6.31	5.24	4.72	4.72	5.25	5.13	
25				5.25	6.22	6.29	5.25	4.72	4.70	5.08	5.07	
26				5.32	6.20	6.31	5.25	4.70	4.70	5.00	5.00	
27				5.20	6.22	6.22	5.25	4.75	4.70	4.95	5.35	
28				5.50	6.35	6.12	5.22	4.60	4.72	4.98	5.32	
29				5.48	6.38	6.04	5.05	4.65	4.78	5.00	5.00	
30				5.45	6.57	6.02	4.95	4.70	4.87	4.98		
31					6.50		5.04	4.75		5.00		
1905.												
1				5.5	6.45	6.83	6.25	5.46	4.8	4.86		
2				5.7	6.43	6.81	6.25	5.54	4.84	4.9		
3				5.52	6.4	6.75	6.25	5.37	4.93	4.92		
4				5.3	6.4	6.65	6.35	5.44	4.87	4.94		
5				5.27	6.37	6.62	6.2	5.48	4.94	4.95		
6				5.27	6.5	6.55	6.0	5.36	4.9	4.93		
7				5.25	6.41	6.57	5.95	5.35	4.87	4.9		
8				5.32	6.43	6.78	5.88	5.37	4.9	4.9		
9				5.35	6.45	6.86	5.85	5.31	4.9	4.9		
10				5.32	6.4	6.8	5.8	5.3	4.96	4.93		
11				5.43	6.46	6.9	5.75	5.33	4.94	4.95		
12				5.36	6.33	6.9	5.68	5.21	4.93	4.97		
13				5.42	6.3	6.95	5.6	5.27	4.91	4.98		
14				5.35	6.25	6.98	5.5	5.16	4.95	5.23		
15				5.37	6.25	7.0	5.35	5.3	4.9	5.15		
16				5.3	6.3	6.95	5.43	5.39	4.87	5.1		
17				5.38	6.25	6.8	5.43	5.13	4.87	5.1		
18				5.62	6.28	6.8	5.4	5.05	4.89	5.08		
19				5.6	6.25	6.8	5.34	5.0	4.97	5.03		
20				5.9	6.28	6.7	5.25	4.96	5.0	5.02		
21				5.57	6.15	6.6	5.37	4.9	4.95	5.07		
22				5.62	6.26	6.65	5.37	4.98	4.9	5.05		
23				5.8	6.25	6.6	5.05	4.95	4.9	5.1		
24				6.0	6.6	6.6	5.32	4.9	4.9	5.08		
25				6.0	6.53	6.5	5.16	4.86	4.92	5.08		
26				6.02	6.5	6.35	5.13	5.06	4.87	5.06		
27				6.2	6.52	6.3	5.43	5.07	4.88	5.08		
28				6.2	6.6	6.25	5.42	4.9	4.87	5.0		
29			5.1	6.2	6.55	6.2	5.38	4.88	4.86	5.1		
30			5.25	6.4	6.57	6.15	5.54	4.9	4.88	5.08		
31			5.27		6.7		5.43	4.88		5.1		
1906.												
1					6.42	7.10	6.20	5.18	4.65	4.76	4.75	
2					6.32	7.15	6.10	5.15	4.60	4.76	4.72	
3					6.22	7.20	6.00	5.15	4.62	4.72	4.72	
4					6.18	7.10	5.90	5.18	4.62	4.72	4.72	
5					6.10	7.05	5.80	5.15	4.60	4.70	4.70	
6					6.05	7.00	5.75	5.15	4.60	4.74	4.72	
7					6.08	6.90	5.70	5.12	4.60	4.73	4.70	
8				6.08	6.08	6.85	5.60	5.15	4.62	4.75	4.70	
9				5.98	6.00	6.70	5.50	5.16	4.62	4.76	4.70	
10				5.88	6.10	6.65	5.90	5.18	4.64	4.75	4.72	
11				5.85	6.15	6.65	5.80	5.15	4.62	4.77		
12				6.00	6.12	6.60	5.70	5.15	4.62	4.75		
13				6.95	6.08	6.60	5.75	5.15	4.60	4.75		
14				6.90	6.05	6.50	5.60	5.15	4.60	4.73		
15				6.00	6.00	6.40	5.75	5.10	4.62	4.72		
16				6.10	6.45	6.40	5.80	5.00	4.64	4.73		
17				6.12	6.48	6.45	5.90	4.95	4.60	4.73		
18				6.15	6.42	6.50	6.00	4.87	4.62	4.75		
19				6.12	6.45	6.55	5.95	4.85	4.64	4.75		
20				6.08	6.40	6.60	5.95	4.80	4.68	4.73		

Mean daily gage height, in feet, of North Platte River, at Bridgeport, 1902–1906—Cont'd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906.												
21				6.00	6.55	6.75	5.90	4.86	4.70	4.75		
22				5.95	6.58	6.70	5.85	4.85	4.70	4.78		
23				5.90	6.60	6.60	5.80	4.90	4.70	4.80		
24				5.98	6.65	6.50	5.78	4.90	4.68	4.84		
25				6.08	6.70	6.40	5.60	4.85	4.65	4.82		
26				6.10	6.70	6.30	5.50	4.90	4.65	4.82		
27				6.15	6.75	6.28	5.50	4.85	4.68	4.82		
28				6.18	6.95	6.25	5.45	4.82	4.70	4.80		
29				6.22	7.20	6.20	5.30	4.80	4.70	4.80		
30				6.30	7.40	6.15	5.20	4.75	4.70	4.78		
31					7.10		5.20	4.70		4.75		

Mean daily discharge, in second-feet, of North Platte River at Bridgeport, 1902–1906.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.								
1			2,170	3,120	480	50	360	800
2			3,180	3,010	290	30	290	680
3			4,170	4,000	380	30	380	760
4		2,610	5,000	2,120	340	20	380	520
5		3,660	5,750	2,270	380	10	460	710
6		3,120	5,390	1,790	360	10	420	
7		3,010	6,200	1,830	380	10	380	
8		3,120	5,000	1,920		10	420	
9		3,550	4,730	1,610	290	40	480	
10			4,790	1,250	250	10	480	
11			5,000	1,350	250	10	590	
12		4,000	4,850	1,060	210	10	680	
13			4,730	840	180	10	560	
14		4,230	5,450	890	930	0	590	
15		4,730	5,750	790	290	10	660	
16		4,550	5,450	1,380	190	10	680	
17		4,860	5,450	890	210	10	620	
18		5,390	4,510	810	160	10	680	
19		5,120	4,350	790	130	0	590	
20		5,450	4,350	540	120	30	620	
21		5,750	3,945	520	110			
22		6,200	3,550	380	100	680	660	
23		5,750	3,020	290	110	520	680	
24		5,750	2,540	320	130	340	680	
25		5,190	2,460	520	60	310	660	
26		4,550	1,580	560	60	680	680	
27		3,390	2,410	640	90	480	560	
28		3,010	3,120	360	110	420	590	790
29		2,170	4,640	300		420	680	
30		2,390	4,510	480		360	660	
31		2,170		560			590	
1903.								
1	2,565	6,700	4,450	6,700	1,365	225	150	675
2	2,295	6,700	4,110	5,910	825	225	225	825
3	1,575	6,300	4,800	6,300	1,170	225	225	825
4	2,040	5,910	5,530	5,910	1,365	225	225	825
5	3,780	6,300	3,780	6,300	1,365	200	90	825
6	4,800	6,300	4,450	4,800	1,170	225	315	990
7	3,780	4,800	5,530	4,450	1,170	225	540	1,170
8	3,780	4,110	6,300	4,110	540	200	420	990
9	3,780	4,800	6,300	2,565	675	200	420	990
10	3,460	5,160	7,510	2,850	825	200	420	825
11	3,150	4,110	7,510	3,460	540	200	675	825
12	2,565	3,780	7,920	2,850	420	200	420	825
13	2,850	4,110	8,340	2,295	825	200	420	
14	2,565	3,460	8,760	2,040	420	200	540	
15	2,850	4,450	8,760	2,040	315	315	540	

72607—IRR 230—09——6

Mean daily discharge, in second-feet, of North Platte River at Bridgeport, 1902–1906—Con.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1903.								
16	2,850	4,110	8,760	2,295	675	225	540	.....
17	3,150	5,160	8,760	2,850	315	200	420	.....
18	3,150	5,530	9,190	1,575	420	200	540	.....
19	5,530	4,800	10,060	1,365	540	200	675	.....
20	3,460	5,910	10,060	2,040	315	200	540	.....
21	3,460	7,100	9,620	1,365	315	200	540	.....
22	3,780	7,100	9,620	1,365	150	225	675	.....
23	3,780	7,510	10,500	1,170	150	420	675	.....
24	3,460	7,920	9,620	825	825	420	675	.....
25	3,780	6,300	9,620	990	225	420	675	.....
26	5,160	5,530	9,190	1,800	225	225	540	.....
27	6,300	5,530	8,760	1,365	420	315	540	.....
28	5,530	5,160	7,920	1,365	90	225	540	.....
29	5,530	6,300	7,510	990	150	225	675	.....
30	5,160	5,910	6,700	2,850	225	225	540	.....
31	.....	4,450	.....	1,170	225	.....	675	.....
1904.								
1	.....	2,200	10,260	6,900	350	200	350	500
2	.....	2,200	10,260	5,640	275	150	275	500
3	.....	2,500	10,260	6,900	150	150	200	500
4	.....	3,200	11,100	5,640	150	100	100	500
5	.....	3,600	9,000	4,400	150	100	150	500
6	.....	6,900	9,000	4,400	200	100	150	425
7	.....	9,000	10,680	5,640	275	100	150	425
8	.....	8,580	11,940	4,400	150	75	150	850
9	.....	5,640	12,360	4,800	150	50	100	1,000
10	1,000	4,800	11,000	5,220	100	50	150	500
11	700	6,480	11,000	4,800	100	75	100	350
12	600	4,400	11,520	2,850	100	75	150	350
13	600	4,000	9,840	2,850	75	75	200	350
14	600	4,000	9,840	2,500	75	75	200	600
15	1,200	4,800	9,420	2,500	75	75	200	850
16	500	4,400	9,420	1,900	150	75	200	850
17	850	4,400	9,000	1,400	275	75	150	700
18	600	4,800	9,840	1,400	425	75	200	700
19	600	4,800	9,000	1,400	350	100	1,650	700
20	600	5,220	9,840	1,200	100	100	1,400	700
21	600	5,640	9,420	1,000	100	100	700	850
22	1,650	6,060	8,580	1,000	150	100	600	700
23	1,000	9,420	9,000	1,200	100	100	600	850
24	4,400	11,520	9,000	1,200	100	100	1,200	850
25	1,200	8,160	9,000	1,200	100	100	700	700
26	1,400	8,160	9,000	1,200	100	100	500	500
27	1,000	8,160	8,160	1,200	150	100	425	1,650
28	2,500	9,420	7,320	1,000	50	100	500	1,400
29	2,500	9,840	6,900	600	75	200	500	500
30	4,900	11,100	6,480	425	100	275	500	.....
31	.....	10,680	.....	600	100	.....	500	.....
1905.								
1	3,700	12,200	16,000	10,200	2,672	200	290	.....
2	5,250	12,000	15,800	10,200	3,192	260	350	.....
3	3,840	11,700	15,200	10,200	2,126	425	400	.....
4	2,400	11,700	14,200	11,200	2,548	305	450	.....
5	2,250	11,400	13,900	9,700	2,796	450	475	.....
6	2,250	12,700	13,200	7,800	2,068	350	425	.....
7	2,150	11,800	13,400	7,375	2,010	305	350	.....
8	2,520	12,000	15,500	6,780	2,126	350	350	.....
9	2,700	12,200	16,300	6,525	1,778	350	350	.....
10	2,520	11,700	15,700	6,100	1,720	500	425	.....
11	3,210	12,300	16,700	5,675	1,894	450	475	.....
12	2,760	11,000	16,700	4,600	1,315	425	525	.....
13	3,140	10,700	17,200	4,200	1,585	375	550	.....
14	2,700	10,200	17,500	3,400	1,134	475	1,405	.....
15	2,820	10,200	17,700	2,400	1,720	350	1,100	.....
16	2,400	10,700	17,200	2,900	2,242	305	930	.....
17	2,880	10,200	15,700	2,800	1,032	305	930	.....
18	4,570	10,500	15,700	2,600	765	335	864	.....
19	4,400	10,200	15,700	2,200	600	525	699	.....
20	6,950	10,500	14,700	1,700	500	600	666	.....

Mean daily discharge, in second-feet, of North Platte River at Bridgeport, 1902–1906—Con.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1905.								
21	4,190	9,225	13,700	2,400	350	475	831	
22	4,570	10,300	14,200	2,126	550	350	765	
23	6,100	10,200	13,700	765	475	350	930	
24	7,800	13,700	13,700	1,836	350	350	864	
25	7,800	13,000	12,700	1,134	290	400	864	
26	7,990	12,700	11,200	1,032	798	305	798	
27	9,700	12,900	10,700	2,486	831	320	864	
28	9,700	13,700	10,200	2,424	350	305	600	
29	9,700	13,200	9,700	2,184	320	290	930	
30	11,700	13,400	9,225	3,192	350	320	864	
31		14,700		2,486	320		930	
1906.								
1		9,400	16,600	7,800	1,120	800	850	560
2		8,400	17,100	6,900	1,050	760	850	530
3		7,500	17,600	6,000	1,100	800	760	530
4		7,250	16,600	5,200	1,210	800	760	530
5		6,550	16,100	4,400	1,150	750	720	500
6		6,100	15,700	4,000	1,150	750	810	530
7		6,400	14,600	3,650	1,180	750	780	400
8	6,000	6,400	14,200	3,000	1,260	800	830	400
9	5,200	5,700	12,600	2,400	1,400	840	750	400
10	4,400	6,500	12,100	5,200	1,500	800	740	400
11	4,150	7,000	12,100	4,400	1,450	800	790	
12	5,450	6,700	11,600	3,650	1,450	660	740	
13	14,500	6,400	11,600	4,050	1,500	660	740	
14	14,000	6,100	10,600	3,000	1,500	720	690	
15	5,450	5,820	9,600	4,050	1,430	760	680	
16	6,300	9,900	9,600	4,400	1,070	660	690	
17	6,450	10,200	10,200	5,200	1,000	720	690	
18	6,750	9,600	10,700	6,000	800	760	640	
19	6,450	9,900	11,200	5,600	810	850	640	
20	6,100	9,450	11,700	5,600	700	900	600	
21	5,450	10,900	13,200	5,200	900	800	640	
22	5,050	11,200	12,700	4,800	860	800	700	
23	4,750	11,400	11,700	4,400	1,090	740	750	
24	5,400	11,900	10,700	4,250	1,090	680	850	
25	6,300	12,400	9,800	3,000	1,030	680	780	
26	6,440	12,600	8,800	2,300	1,190	680	780	
27	6,900	13,000	8,600	2,300	1,120	740	780	
28	7,150	15,100	8,250	2,150	1,040	800	660	
29	7,500	17,300	7,800	2,450	1,060	800	660	
30	8,220	19,700	7,300	1,140	950	730	640	
31		16,600		1,140	920		560	

Estimated monthly discharge of North Platte River at Bridgeport, 1902–1906.

[Drainage area, 24,800 square miles.]

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
April.								
1903	6,300	1,570	3,664	218,000	0.148	0.16	11	1.37
1904 [a]	4,400	536	1,393	58,000				.91
1905	11,700	2,150	4,822	286,900	.194	.22	6	3.42
1906	14,500	4,150	6,710	399,300	.275	.31	16	1.88
May.								
1902 [b]	6,200	2,170	4,149	255,000				1.86
1903	7,920	3,460	5,526	339,800	.223	.26	14	1.83
1904	11,350	2,250	6,313	388,200	.254	.29	10	2.78
1905	14,700	9,220	11,710	720,000	.472	.54	16	3.29
1906	19,700	5,700	9,790	602,000	.394	.45	17	2.61
June.								
1902	6,200	1,580	4,267	253,900	.172	.19	7	2.62
1903	10,500	3,780	7,665	456,100	.308	.34	23	1.45
1904	12,190	6,650	9,630	573,000	.389	.43	15	2.81
1905	17,700	9,220	14,430	858,600	.582	.65	51	1.28
1906	17,600	7,300	12,000	714,000	.484	.54	30	1.78
July.								
1902	4,000	290	1,200	73,800	.048	.05	3	1.44
1903	6,700	825	2,837	174,400	.112	.12	6	2.02
1904	6,900	470	2,940	180,800	.119	.13	8	1.52
1905	11,200	765	4,536	278,900	.183	.20	9	2.31
1906	7,800	1,140	4,120	253,000	.166	.18	13	1.37
August.								
1902	930	60	244	15,000	.010	.01	1	.90
1903	1,360	90	589	36,200	.024	.03	2	1.56
1904	470	50	157	9,600	.006	.01	2	.63
1905	3,190	290	1,316	80,900	.053	.06	5	1.17
1906	1,500	700	1,130	69,500	.045	.05	3	1.76
September.								
1902	680	0	162	9,600	.007	.01	.5	1.96
1903	420	200	240	14,300	.010	.01	.6	1.66
1904	312	50	108	6,400	.004	.004	.4	.93
1905	600	200	370	22,000	.015	.02	2	1.25
1906	900	660	760	45,200	.031	.03	2	1.64
October.								
1902	680	290	559	34,400	.022	.02	2	.85
1903	675	90	487	29,900	.020	.02	4	.52
1904	1,850	100	464	28,600	.019	.02	2	.86
1905	1,400	290	685	42,100	.028	.03	4	.80
1906	850	560	727	44,700	.029	.03	1	2.00
November.								
1903 [c]	1,170	675	883	21,000				.26
1904	1,850	360	846	48,700	.034	.04	200	.02
1906 [d]	560	400	478	9,500				.86

[a] April 10 to 30. [b] 25 days in May. [c] November 1 to 12. [d] November 1 to 10.

NORTH PLATTE RIVER AT NORTH PLATTE.

The station at North Platte, the lowest on North Platte River, was established October 5, 1894. It is 3½ miles above the junction of the North and South Platte, at a highway bridge about one-half mile north of the city of North Platte, in sec. 28, T. 14 N., R. 30 W., and is shown on the North Platte topographic atlas sheet.

The river is straight for a considerable distance above and below the station. The bed is composed of shifting sand, and the banks are low but not liable to overflow. The river flows in two channels. The

north channel is narrow and is dry, except in moderately high water. At low stages the water is confined to a few channels along the right bank of the main channel. During the winter months the river often freezes almost entirely solid, as it is very shallow, and attempts to obtain records of winter flow have been somewhat unsuccessful. The range of gage heights is about 5 feet. There is one small tributary, Birdwood Creek, which maintains a small flow of water at the gaging station during the months when the river itself would otherwise be entirely dry. The only obstructions in the channel are the piling bents and inclined ice guards. The water is never sluggish even at low stages.

Measurements are made from the highway bridge, which consists of 93 spans of 20 feet each, supported on pile bents.

The gage is a vertical staff, marked to tenths of a foot, spiked to a piling of the Union Pacific Railroad bridge, 2 miles below the highway bridge. The bench mark is the top of the east rail directly over the gage rod; elevation, 12 feet above the zero of the gage. It is customary to refer the elevation of the water surface at the gaging section, at the time of making measurements, to the top of the upstream end of the cap of the second bent from the right-bank end of the highway bridge.

Discharge measurements of North Platte River at North Platte, 1892–1906.

Date.	Hydrographer.	Gage height.	Discharge.
1892.		*Feet.*	*Sec.-ft.*
September 14	Cyrus C. Babb		770
November 2	do		1,070
November 22	do		1,370
1894.			
October 5	C. P. Ross		620
November 6	do		1,227
1895.			
March 27	do	2.25	2,329
April 29	do	2.85	5,695
May 28	do	2.90	6,320
June 8	do	4.00	16,261
September 14	O. V. P. Stout	1.30	200
1896.			
June 13	do	3.35	9,000
June 29	do	2.90	4,000
July 25	do	2.05	1,260
September 8	do	1.50	547
1897.			
April 5	C. P. Ross	2.70	4,038
April 12	do	2.80	2,961
April 26	do	3.45	10,328
May 17	do	3.50	13,486
May 29	do	4.05	20,796
May 29	do	4.05	20,796
June 10	do	3.95	17,172
June 19	do	3.35	11,393
June 29	do	3.05	6,518
July 10	do	2.25	4,112
July 24	do	2.05	2,940
August 7	do	2.40	3,118
August 21	do	2.15	2,306
September 4	do	1.65	679
September 18	do	1.70	744
1897.			
October 6	C. P. Ross	1.50	486
October 18	do	1.90	1,343
November 11	do	1.90	1,511
1898.			
April 15	do	2.10	1,844
May 2	do	2.60	4,429
May 14	do	2.50	4,288
May 23	do	2.90	5,296
May 31	do	2.60	10,074
June 4	do	3.25	8,270
June 23	do	3.00	5,848
July 22	do	1.70	697
July 30	do	1.20	324
August 15	do	.80	241
August 23	do	1.00	197
September 2	A. B. McCoskey	.45	12
September 9	C. P. Ross	.90	219
September 27	do	1.20	364
October 11	do	1.30	306
October 26	do	1.65	801
November 7	do	1.80	1,014
1899.			
April 19	Glenn E. Smith	3.30	9,111
May 6	do	3.00	8,239
May 22	do	3.80	12,962
June 6	do	3.60	13,310
June 15	C. P. Ross	3.60	11,330
June 19	Glenn E. Smith	4.20	16,257
July 17	C. P. Ross	3.30	10,351
August 8	do	2.50	4,637
August 28	do	1.85	2,013
September 15	do	1.55	976
October 4	do	1.70	713
1900.			
December 20	Adna Dobson	2.30	1,223

Discharge measurements of North Platte River at North Platte, 1892–1906—Continued.

Date.	Hydrographer.	Gage height.	Discharge.
1901.		*Feet.*	*Sec.-ft.*
July 17	O. V. P. Stout	1.80	943
August 29	H. O. Smith	1.40	198
December 27	F. Dobson	Ice.	1,536
1902.			
April 9	B. E. Forbes	2.20	1,804
May 6	H. O. Smith	2.65	3,723
May 20	do	3.15	7,156
June 3	do	2.50	3,029
June 19	do	3.00	6,615
July 3	do	2.70	4,997
July 17	do	1.65	1,343
July 28	do	1.70	677
August 9	do	1.00	55
August 18	do	1.00	49
August 23	do	1.00	94
September 6	J. C. Stevens	1.00	20
September 24	H. O. Smith	2.30	1,818
November 29	do	2.40	822
1903.			
April 2	J. C. Stevens	2.30	2,143
May 8	do	2.85	5,004
June 13	do	2.90	6,490
June 29	do	3.25	9,114
July 8	do	2.80	4,768
July 31	do	1.85	787
August 14	do	1.80	791
September 17	W. C. Sturdevant	1.60	492
October 31	J. C. Stevens	2.00	1,145
1904.		*Feet.*	*Sec.-ft.*
March 26	J. C. Stevens	2.20	1,086
May 13	do	2.80	4,995
May 27	R. D. Hubbard	3.40	9,445
June 13	J. C. Stevens	3.85	14,619
July 26	do	2.05	1,488
September 28	R. D. Hubbard	1.57	422
1905.			
March 31	G. W. Bates	2.40	2,157
May 16	do	3.35	9,677
June 12	H. C. Gardner	3.95	17,570
June 20	do	3.75	16,010
July 13	do	2.75	5,878
July 22	do	2.40	3,513
August 5	do	2.20	2,564
September 20	F. S. Dobson	1.80	703
October 24	Dobson and Bates	1.98	1,056
September 9	H. C. Gardner	1.70	735
1906.			
February 22	F. S. Dobson	2.65	5,095
April 10	do	2.80	5,929
May 9	do	2.60	5,502
July 2	Arthur Dobson	2.85	6,334
August 1	do	2.00	1,530
September 7	do	1.75	1,035
November 3	do	2.52	3,134
November 13	A. R. Wilson	2.35	2,566

Mean daily gage height, in feet, of North Platte River at North Platte, 1895–1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1895.												
1			3.40	2.05	2.75	3.35	2.75	1.65	1.45	1.40	1.85	2.10
2			3.15	2.25	2.85	3.20	2.65	1.60	1.45	1.30	1.80	2.00
3			2.70	2.00	2.85	3.15	2.50	1.85	1.45	1.35	1.85	1.90
4			2.70	2.00	3.20	3.65	2.60	1.70	1.30	1.50	1.95	2.10
5			2.70	2.10	3.35	3.65	2.65	1.60	1.30	1.50	2.00	2.35
6			2.55	2.35	3.45	3.60	2.55	1.65	1.30	1.50	1.95	2.30
7			2.40	2.45	3.45	4.05	2.55	1.75	1.20	1.50	1.85	2.40
8			2.65	2.40	3.25	3.95	2.65	1.75	1.20	1.60	1.85	2.45
9			2.35	2.20	3.00	3.95	2.75	1.65	1.25	1.70	1.95	2.50
10			2.05	2.00	3.05	3.90	2.85	1.65	1.25	1.70	1.80	2.45
11			2.45	2.30	3.05	3.85	2.75	1.65	1.25	1.60	1.85	2.45
12			2.35	2.30	2.90	3.65	2.65	1.65	1.25	1.75	1.90	2.45
13			1.80	2.35	2.80	3.55	2.55	1.60	1.30	1.70	2.10	2.50
14			1.60	2.25	2.70	3.65	2.55	1.50	1.30	1.75	2.00	2.65
15			1.55	2.05	2.85	3.55	2.45	1.55	1.25	1.75	2.00	2.45
16			1.95	2.25	2.85	3.55	2.35	1.65	1.40	1.85	2.00	2.45
17			2.05	2.40	3.00	3.65	2.15	1.55	1.40	1.85	1.90	2.45
18			2.20	2.50	3.15	3.45	2.00	1.50	1.30	1.85	1.95	2.45
19			2.25	2.45	2.95	3.45	2.00	1.45	1.30	1.80	1.90	2.45
20			2.35	2.35	3.00	3.35	2.10	1.50	1.20	1.75	1.95	2.50
21			2.20	2.60	2.95	3.25	2.00	1.40	1.30	1.75	1.80	2.60
22			2.15	2.75	3.00	3.40	2.05	1.35	1.35	1.75	1.85	2.55
23			2.15	2.75	3.00	3.25	2.15	1.40	1.55	1.85	1.90	2.60
24			2.20	2.70	3.05	3.25	2.35	1.35	1.50	1.85	2.00	2.65
25		3.25	2.20	2.70	2.95	3.20	2.35	1.40	1.45	1.90	2.10	2.65
26		3.40	2.45	2.60	2.90	3.10	2.15	1.30	1.40	1.90	2.10	2.55
27		3.30	2.25	2.75	2.90	3.10	2.00	1.25	1.40	1.95	2.00	2.50
28		3.20	2.20	2.85	2.85	3.05	2.00	1.60	1.30	1.85	2.00	2.45
29			2.15	2.95	2.75	2.90	1.95	1.55	1.35	1.85	1.90	.....
30			2.05	2.95	3.05	2.85	1.90	1.50	1.45	1.75	2.00	.....
31			1.95	.....	3.35	.....	1.75	1.45	.....	1.90	.....	.....

Mean daily gage height, in feet, of North Platte River at North Platte, 1895–1906—Con.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1896.												
1	2.50	2.85	.....	.....	2.70	2.75	2.55	2.20	1.50	1.90	2.45	2.40
2	2.50	2.90	.....	.....	2.75	2.90	2.55	2.15	1.75	1.80	2.50	2.40
3	2.50	2.80	.....	.....	2.65	2.75	2.45	2.25	1.65	1.75	2.35	2.40
4	2.50	2.80	.....	.....	2.85	2.55	2.35	2.30	1.65	1.70	2.20	2.30
5	2.60	2.65	.....	.....	2.95	3.85	2.25	2.05	1.60	1.75	2.15	2.30
6	2.60	2.50	.....	.....	3.15	4.00	2.20	2.15	1.60	1.70	1.90	2.30
7	2.60	2.45	.....	.....	3.05	3.85	2.15	2.25	1.50	1.85	1.80	2.40
8	2.60	2.05	.....	.....	3.15	3.70	2.00	2.05	1.50	1.90	1.70	2.45
9	2.65	2.00	.....	.....	3.00	3.55	2.00	1.80	1.60	1.85	1.85	2.55
10	2.75	2.05	.....	2.30	2.90	3.45	1.90	1.90	1.70	1.90	1.95	2.65
11	2.80	1.95	.....	2.45	2.90	3.35	1.80	1.70	1.80	1.80	2.05	2.65
12	2.70	2.45	.....	2.65	2.85	3.35	1.60	1.60	1.80	1.85	2.10	2.75
13	2.70	2.75	.....	2.80	2.95	3.35	1.50	1.60	1.90	1.85	2.20	2.75
14	2.70	2.60	.....	2.65	3.05	3.20	1.35	1.50	2.00	1.85	2.10	2.75
15	2.70	2.35	.....	2.55	3.25	3.05	1.10	1.45	2.00	1.85	2.15	2.75
16	2.70	2.35	.....	2.50	3.05	2.90	1.15	1.35	1.90	1.90	2.05	2.65
17	2.75	2.25	.....	2.60	3.05	2.85	1.05	1.45	1.80	1.90	2.25	2.70
18	2.70	2.15	.....	2.60	3.10	2.85	1.00	1.65	1.85	1.80	2.25	2.50
19	2.75	2.25	.....	2.50	3.00	3.00	1.15	1.80	1.90	1.80	2.35	2.55
20	2.75	2.45	.....	2.55	3.05	2.90	1.25	1.85	1.85	1.80	1.90	2.55
21	2.80	2.35	.....	2.70	3.05	2.85	1.50	2.00	1.85	1.80	2.00	2.55
22	2.80	2.40	.....	2.55	3.00	2.80	1.85	1.90	1.90	1.90	1.85	2.50
23	2.80	2.40	.....	2.65	2.90	2.70	2.20	1.80	1.80	2.00	1.95	2.60
24	2.80	2.45	.....	2.55	2.90	2.80	2.45	1.90	1.85	1.90	2.15	2.65
25	2.85	2.35	.....	2.70	2.85	2.95	2.05	1.75	1.90	1.90	2.25	2.75
26	2.90	2.30	.....	2.65	2.80	2.85	1.95	1.60	2.00	1.90	2.30	2.75
27	2.90	2.35	.....	2.55	2.70	2.80	1.85	1.50	2.00	1.90	2.40	2.70
28	2.90	2.30	.....	2.55	2.70	2.80	1.70	1.60	2.05	1.80	2.40	2.75
29	2.90	2.40	.....	2.65	2.55	2.90	2.00	1.55	2.05	1.95	2.40	2.85
30	2.90	.....	.....	2.65	2.55	2.55	1.95	1.50	2.00	1.95	2.40	2.85
31	2.85	.....	.....	.....	2.60	.....	2.15	1.60	.....	2.25	.....	2.85
1897.												
1	2.90	2.80	2.50	2.30	3.20	4.10	2.95	1.85	1.75	1.60	2.00	2.30
2	2.85	2.80	2.60	2.55	3.20	4.05	2.80	1.85	1.75	1.50	1.90	2.20
3	3.00	2.80	2.75	2.75	3.25	4.05	2.75	1.85	1.70	1.50	1.80	2.30
4	2.95	2.90	2.85	2.75	3.50	3.90	2.65	1.90	1.65	1.50	1.70	2.30
5	3.00	2.85	2.90	2.85	3.50	3.90	2.55	1.95	1.60	1.50	1.70	2.30
6	3.05	2.85	3.00	2.70	3.45	3.90	2.50	2.45	1.65	1.50	1.80	2.30
7	3.10	2.85	3.05	2.75	3.50	4.10	2.40	2.40	1.55	1.50	1.90	2.30
8	3.15	2.85	3.10	2.85	3.50	4.25	2.35	2.50	1.45	1.50	1.90	2.30
9	3.20	2.95	3.15	2.75	3.65	4.15	2.45	2.40	1.45	1.50	2.00	2.40
10	3.15	3.05	3.25	2.65	3.60	3.90	2.25	2.45	1.50	1.65	2.00	2.45
11	3.15	3.15	3.35	2.65	3.60	3.85	2.10	2.50	1.65	1.55	1.90	2.50
12	3.15	3.15	2.45	2.80	3.65	3.85	2.15	2.35	1.70	1.65	1.90	2.55
13	3.25	3.20	2.50	2.65	3.65	3.55	2.35	2.20	1.60	1.70	1.90	2.70
14	3.25	3.25	2.40	2.55	3.60	3.40	2.10	2.30	1.65	1.65	1.90	2.70
15	3.15	3.25	2.30	2.45	3.65	3.25	2.05	2.45	1.60	1.70	1.90	2.80
16	3.20	3.35	2.25	2.25	3.45	3.35	2.15	2.35	1.65	1.80	1.90	2.80
17	3.20	3.35	2.40	2.25	3.55	3.35	2.15	2.35	1.65	1.85	2.00	2.90
18	3.20	3.35	2.55	2.30	3.45	3.45	2.20	2.35	1.65	1.90	2.00	2.90
19	3.20	3.35	2.25	2.30	3.45	3.35	2.15	2.30	1.60	1.90	2.00	2.90
20	3.20	3.35	2.20	2.35	3.55	3.35	2.35	2.20	1.60	1.80	2.00	2.90
21	3.15	3.35	2.45	2.55	3.50	3.35	2.15	2.15	1.60	1.80	2.00	2.90
22	3.05	3.25	2.40	2.65	3.55	3.35	2.25	2.15	1.60	1.70	1.95	2.90
23	2.90	3.15	2.40	2.85	3.55	3.35	2.40	1.95	1.55	1.70	2.00	2.80
24	2.80	3.05	2.30	3.05	3.60	3.25	2.05	1.90	1.50	1.70	2.00	2.80
25	2.80	2.25	2.05	3.25	3.70	3.25	2.00	1.85	1.55	1.70	1.80	2.70
26	2.90	2.30	2.05	3.45	3.85	3.10	1.95	1.85	1.55	1.85	1.95	2.70
27	2.90	2.30	2.20	3.55	4.00	3.05	1.95	1.80	1.50	1.90	2.15	2.70
28	2.90	2.30	2.10	3.35	4.05	3.10	1.95	1.80	1.50	2.20	2.30	2.60
29	2.90	.....	2.05	3.25	4.05	3.05	1.95	1.75	1.50	2.25	2.30	2.70
30	2.90	.....	2.15	3.20	4.10	3.05	1.90	1.70	1.50	2.20	2.30	2.80
31	2.90	.....	2.20	.....	4.05	.....	1.85	1.70	.....	2.05	.....	2.80
1898.												
1	2.80	2.90	2.40	2.40	2.55	3.75	2.65	1.50	0.35	1.20	1.70	2.20
2	2.90	2.90	2.30	2.30	2.60	3.50	2.60	1.90	.45	1.10	1.70	2.20
3	2.90	2.80	2.15	2.25	2.70	3.35	2.60	1.95	.55	1.00	1.70	2.20
4	2.80	2.90	2.15	2.15	2.70	3.30	2.70	1.75	.55	1.10	1.70	2.30
5	2.90	2.90	2.10	2.30	2.70	3.25	2.55	1.45	.65	1.10	1.80	2.30

Mean daily gage height, in feet, of North Platte River at North Platte, 1895–1906—Con.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1898.												
6	2.90	2.90	2.05	2.40	2.70	3.20	2.50	1.40	0.50	1.20	1.80	2.30
7	2.90	2.90	2.05	2.30	2.75	3.20	2.45	1.50	.60	1.20	1.80	2.30
8	3.00	3.00	2.15	2.35	2.70	3.10	2.25	1.40	.75	1.20	1.70	2.30
9	3.00	3.05	2.25	2.25	2.70	3.10	2.20	1.30	.90	1.35	1.80	2.30
10	2.90	3.00	2.25	2.05	2.70	3.10	2.50	1.20	1.20	1.30	1.65	2.30
11	2.90	3.05	2.25	2.15	2.60	3.10	2.30	1.15	1.35	1.30	1.70	2.50
12	2.80	3.20	2.25	2.25	2.60	3.10	3.40	1.10	1.65	1.35	1.80	2.50
13	2.85	3.20	2.20	2.30	2.55	3.05	2.10	1.00	1.50	1.30	1.80	2.50
14	2.90	3.25	2.15	2.20	2.50	3.25	2.00	.90	1.70	1.30	1.80	2.50
15	2.80	3.20	2.25	2.10	2.55	3.15	1.90	.80	1.80	1.30	1.70	2.50
16	2.85	3.05	2.15	2.20	2.65	3.05	1.80	.80	1.70	1.30	1.85	2.50
17	2.80	2.90	2.20	2.00	3.10	3.00	1.85	.80	1.65	1.30	1.80	2.50
18	2.90	2.85	2.10	2.05	2.90	3.05	1.80	.80	1.50	1.30	1.90	2.50
19	2.85	2.80	2.25	2.05	2.80	3.10	1.80	.75	1.40	1.40	2.10	2.50
20	2.80	2.80	2.25	2.15	2.80	3.15	1.70	.60	1.30	1.50	2.00	2.50
21	2.80	2.80	2.30	2.15	2.90	3.10	1.70	.60	1.25	1.50	1.85	2.60
22	2.80	2.70	2.15	2.15	2.85	3.00	1.70	.60	1.20	1.50	1.80	2.60
23	2.85	2.65	2.00	2.25	2.90	3.00	1.60	1.00	1.20	1.60	1.80	2.60
24	2.90	2.55	2.00	2.20	2.80	3.00	1.60	1.05	1.20	1.60	1.80	2.60
25	2.80	2.50	1.95	2.25	2.80	3.00	1.65	.85	1.20	1.60	1.80	2.60
26	2.90	2.45	1.90	2.35	2.90	2.90	1.60	.75	1.20	1.65	1.80	2.60
27	2.90	2.45	2.05	2.55	3.10	2.90	1.60	.70	1.20	1.70	1.80	2.70
28	2.90	2.35	2.25	2.55	3.10	2.85	1.45	.55	1.10	1.70	2.10	2.70
29	2.90	.....	2.45	2.55	3.00	2.70	1.30	.65	1.10	1.70	2.20	2.70
30	2.90	.....	2.35	2.55	3.95	2.75	1.20	.55	1.15	1.70	2.20	2.70
31	2.90	.....	2.30	.....	3.60	.....	1.40	.50	.....	1.70	.....	2.70
1899.												
1	2.70	3.00	3.00	2.30	3.50	3.55	4.10	2.60	1.90	1.55	1.90	2.10
2	2.70	3.00	3.00	2.10	3.50	3.70	4.20	2.70	1.80	1.50	2.00	2.10
3	2.70	3.00	3.00	2.80	3.40	3.80	4.15	2.70	1.80	1.60	2.00	2.05
4	2.70	3.00	3.00	2.70	3.25	3.80	4.10	2.80	1.80	1.70	2.05	2.05
5	2.70	3.00	3.00	2.60	3.15	3.70	4.10	2.80	1.65	1.70	2.10	2.30
6	2.70	3.00	3.00	2.80	3.00	3.60	4.10	2.70	1.65	1.70	2.15	2.50
7	2.70	3.00	3.00	2.85	3.00	3.65	4.00	2.65	1.70	1.70	2.10	2.50
8	2.70	3.00	3.00	2.55	3.25	3.80	4.00	2.50	1.70	1.60	2.10	2.50
9	2.70	3.00	3.00	2.50	3.15	3.90	4.00	2.50	1.60	1.60	2.10	2.40
10	2.70	3.00	3.10	2.50	2.80	3.90	4.00	2.40	1.55	1.60	2.10	2.40
11	2.70	3.00	3.10	2.50	2.75	3.85	3.90	2.30	1.60	1.60	2.10	2.40
12	2.70	3.00	3.10	2.60	2.60	3.75	3.65	2.30	1.60	1.70	2.10	2.40
13	2.70	3.00	3.10	2.65	2.60	3.65	3.60	2.35	1.60	1.70	2.00	2.40
14	2.70	3.00	3.10	2.50	2.50	3.55	3.60	2.50	1.60	1.65	2.00	2.40
15	2.70	3.00	3.10	2.45	2.60	3.60	3.55	2.50	1.55	1.80	2.05	2.40
16	2.70	3.00	3.10	2.50	2.65	3.70	3.40	2.40	1.50	1.80	2.10	2.40
17	2.70	3.00	3.00	3.25	2.85	3.95	3.30	2.35	1.50	1.80	2.05	2.40
18	2.70	3.00	2.80	3.30	3.05	4.00	3.20	2.40	1.50	1.80	2.00	2.40
19	2.80	3.00	2.80	3.35	3.05	4.20	3.25	2.30	1.50	1.80	2.10	2.40
20	2.80	3.00	2.80	3.40	3.40	4.15	3.30	2.30	1.50	1.80	2.10	2.40
21	2.80	3.00	2.50	3.30	3.60	3.95	3.30	2.30	1.60	1.80	2.20	2.40
22	2.90	3.00	2.80	3.10	3.75	3.85	3.20	2.00	1.60	1.80	2.20	2.40
23	2.80	3.00	2.80	3.10	3.75	3.90	3.15	2.00	1.50	1.80	2.10	2.40
24	2.80	3.00	3.05	3.10	3.80	3.85	3.00	1.90	1.50	1.80	2.10	2.45
25	3.00	3.00	2.90	3.00	3.70	4.15	2.95	1.90	1.50	1.80	2.10	2.55
26	3.00	3.00	2.60	2.90	3.80	4.30	2.80	1.90	1.60	1.90	2.10	2.70
27	3.00	3.00	2.60	3.00	3.85	4.45	2.80	1.90	1.60	2.00	2.10	2.70
28	3.00	3.00	2.55	3.00	3.85	4.40	2.85	1.85	1.55	2.00	2.20	2.70
29	3.00	.....	2.50	3.00	3.75	4.30	2.70	1.75	1.60	2.00	2.10	2.70
30	3.00	.....	2.55	3.10	3.50	4.25	2.70	1.65	1.60	2.00	2.10	2.70
31	3.00	.....	2.60	.....	3.50	.....	2.55	1.75	.....	1.95	.....	2.65
1900.												
1	2.40	2.00	2.70	2.30	3.20	3.45	2.85	1.85	0.80	1.40	1.80	2.10
2	2.35	2.05	2.85	2.30	3.15	3.50	2.60	1.75	.80	1.40	1.80	2.20
3	2.20	2.20	3.00	2.20	3.35	3.50	2.60	1.60	.80	1.40	1.80	2.20
4	2.35	2.20	3.10	2.25	3.30	3.65	2.60	1.45	.80	1.40	1.80	2.25
5	2.40	2.25	3.10	2.30	3.35	3.80	2.90	1.50	.80	1.30	1.70	2.10
6	2.50	2.35	3.10	2.40	3.50	3.85	2.80	1.80	.80	1.30	1.70	2.30
7	2.60	2.35	2.80	2.50	3.50	3.85	2.80	2.30	.80	1.30	1.75	2.35
8	2.70	2.25	2.80	2.60	3.40	3.90	2.65	1.95	.80	1.30	1.80	2.30
9	2.80	2.20	2.80	2.50	3.25	3.80	2.45	1.95	.80	1.30	1.80	2.30
10	2.80	2.30	2.80	2.50	3.20	3.75	2.20	1.65	.95	1.30	1.70	2.20

Mean daily gage height, in feet, of North Platte River at North Platte, 1895–1906—Con.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1900.												
11	2.80	2.40	2.75	2.55	3.20	3.70	2.15	1.60	0.90	1.30	1.75	2.25
12	2.90	2.40	2.50	2.60	3.20	3.60	2.10	1.60	.90	1.40	1.85	2.30
13	2.90	2.30	2.30	2.65	3.25	3.50	2.20	1.50	.90	1.40	1.80	2.30
14	2.90	2.30	2.15	2.60	3.30	3.50	2.10	1.45	.80	1.40	1.85	2.30
15	2.95	2.60	2.00	2.70	3.30	3.55	2.10	1.30	.80	1.40	1.90	2.20
16	3.00	2.40	2.40	2.90	3.30	3.60	2.15	1.30	.90	1.40	1.85	2.20
17	3.00	2.30	2.80	2.90	3.30	3.60	2.10	1.25	.90	1.50	1.80	2.20
18	3.00	2.35	2.30	2.90	3.45	3.60	2.05	1.15	.95	1.50	1.75	2.20
19	2.85	2.40	2.10	2.80	3.60	3.45	1.90	1.10	.95	1.50	1.60	2.20
20	2.85	2.50	2.00	2.70	3.60	3.30	2.00	.95	.95	1.50	1.70	2.30
21	2.75	2.50	2.40	2.65	3.50	3.30	2.00	1.45	.90	1.50	1.95	2.30
22	2.60	2.65	2.50	2.70	3.50	3.20	2.00	1.50	.90	1.50	1.95	2.40
23	2.65	2.70	2.40	2.80	3.45	3.10	2.10	1.35	.90	1.50	2.00	2.00
24	2.70	2.80	2.50	2.90	3.40	3.10	2.35	1.50	.90	1.60	1.95	2.00
25	2.50	2.80	2.45	3.00	3.40	3.10	2.35	1.45	.90	1.70	2.20	2.40
26	2.55	2.70	2.40	3.10	3.35	3.00	2.50	1.40	.90	1.60	2.25	2.45
27	2.00	2.60	2.40	3.10	3.30	2.90	2.35	1.20	1.00	1.60	2.30	1.85
28	1.70	2.60	2.30	3.05	3.25	2.90	2.00	1.20	1.10	1.60	2.15	1.80
29	1.90	.....	2.30	2.90	3.20	2.80	2.00	1.00	1.10	1.65	2.00	1.60
30	2.00	.....	2.25	2.95	3.20	2.80	2.00	1.00	1.25	1.70	2.00	.....
31	2.00	.....	2.30	.....	3.40	.....	1.90	.90	.....	1.75	.....	.....
1901.												
1	2.10	2.70	3.15	2.60	2.30	3.35	2.70	1.10	1.95	1.60	2.00	.....
2	2.10	2.60	3.40	2.60	2.90	3.25	2.60	1.10	1.95	1.60	2.00	.....
3	2.20	2.50	3.15	2.60	3.05	3.20	2.60	1.00	1.85	1.60	2.00	.....
4	2.90	2.45	3.20	2.40	3.00	3.20	2.60	.90	1.95	1.65	2.00	.....
5	2.50	2.40	3.20	2.25	3.10	3.40	2.50	.80	2.00	1.70	2.00	.....
6	2.50	2.50	2.70	2.30	3.10	3.50	2.50	.80	2.00	1.75	2.00	.....
7	2.50	2.55	2.30	2.25	3.05	3.50	2.45	.75	2.00	1.95	1.95	.....
8	2.50	2.60	2.50	2.10	3.00	3.60	2.40	.80	2.05	1.85	2.00	.....
9	2.50	2.60	2.50	2.10	3.00	3.60	2.35	.95	2.00	1.80	2.00	.....
10	2.50	2.60	2.40	2.30	3.00	3.60	2.25	.85	1.95	2.00	2.00	.....
11	2.50	2.60	2.50	2.65	3.10	3.60	2.20	1.10	2.10	2.05	2.00	.....
12	2.50	2.50	2.30	2.80	3.00	3.90	2.20	1.40	2.15	2.00	2.10	.....
13	2.50	2.50	2.20	2.65	3.00	3.40	2.15	1.40	2.15	1.85	2.10	.....
14	2.50	2.45	2.15	2.50	3.00	3.45	2.00	1.25	2.00	1.90	2.10	.....
15	2.55	2.55	2.30	2.50	3.00	3.50	1.95	1.20	1.85	1.85	2.15	.....
16	2.60	2.80	2.20	2.40	3.00	3.50	1.80	1.30	1.75	1.90	2.20	.....
17	2.60	2.90	2.20	2.40	2.90	3.45	1.80	1.30	1.70	1.90	2.20	.....
18	2.60	2.90	2.20	2.35	2.90	3.35	1.80	1.30	1.75	1.90	2.20	.....
19	2.70	2.90	2.50	2.30	2.90	3.30	1.80	1.25	1.90	1.90	2.20	.....
20	2.70	2.85	2.15	2.30	2.95	3.60	1.80	1.20	1.90	1.90	2.20	.....
21	2.70	2.80	2.20	2.30	3.00	3.35	1.60	1.65	1.85	2.00	2.20	.....
22	2.85	2.90	2.20	2.20	3.05	3.20	1.35	1.70	1.70	2.00	2.20	.....
23	2.90	3.00	2.20	2.20	3.40	3.45	1.20	1.45	1.60	2.00	2.20	.....
24	3.00	3.00	2.20	2.15	3.45	3.25	1.10	1.40	1.60	2.00	2.20	.....
25	3.00	3.00	2.10	2.10	3.50	3.20	1.00	1.30	1.60	2.00	2.20	.....
26	3.00	2.90	2.10	2.10	3.60	3.05	1.50	1.25	1.60	2.00	2.20	.....
27	3.00	2.95	2.20	2.10	3.60	3.00	1.40	1.30	1.50	2.00	2.20	.....
28	2.95	3.00	2.00	2.15	3.70	2.90	1.25	1.35	1.50	2.00	2.20	.....
29	2.90	.....	2.00	2.30	3.65	2.80	.90	1.40	1.50	2.00	2.10	.....
30	2.80	.....	2.20	2.30	3.50	2.70	.80	1.40	1.35	2.00	2.10	.....
31	2.75	.....	3.20	.....	3.40	.....	1.15	1.70	.....	2.00	.....	.....
1902.												
1	.....	.....	.....	2.00	2.70	2.60	2.80	1.50	1.10	1.90	2.00	2.20
2	.....	.....	.....	2.25	2.70	2.60	2.80	1.35	1.05	1.90	2.00	2.25
3	.....	.....	.....	2.30	2.60	2.50	2.70	1.20	1.00	1.90	2.00	2.30
4	.....	.....	.....	2.40	2.60	2.50	2.60	1.10	1.00	1.95	2.00	2.30
5	.....	.....	.....	2.40	2.70	2.45	2.50	1.10	1.00	2.00	2.00	2.30
6	.....	.....	.....	2.40	2.65	2.65	2.50	1.15	1.00	1.95	2.00	2.30
7	.....	.....	.....	2.25	2.60	2.95	2.50	1.00	1.00	1.90	2.00	.....
8	.....	.....	.....	2.20	2.60	2.90	2.40	1.00	1.00	1.85	2.00	.....
9	.....	.....	.....	2.20	2.60	3.00	2.50	1.00	1.00	1.75	2.00	.....
10	.....	.....	.....	2.15	2.60	2.90	2.35	1.05	.95	1.70	2.00	.....
11	.....	.....	.....	2.10	2.60	2.75	2.30	1.00	1.00	2.05	2.00	.....
12	.....	.....	.....	2.00	2.75	3.05	2.20	.90	1.10	2.00	2.00	.....
13	.....	.....	.....	2.05	2.90	2.95	2.10	.90	1.15	2.00	2.00	.....
14	.....	.....	.....	2.15	2.90	3.00	2.00	1.05	1.10	2.00	2.00	.....
15	.....	.....	.....	2.30	3.00	3.00	2.00	1.05	1.20	2.00	2.10	.....

Mean daily gage height, in feet, of North Platte River at North Platte, 1895–1906—Con.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
16	.....	.....	1.80	2.40	3.40	3.00	1.75	1.00	1.15	2.00	2.10	.....
17	.....	.....	2.05	2.40	3.20	2.95	1.50	.90	1.10	2.00	2.10	.....
18	.....	.....	2.20	2.35	3.05	3.00	1.60	1.00	1.20	1.95	2.10	.....
19	.....	.....	2.20	2.40	3.10	3.00	1.70	1.10	1.15	1.90	2.10	.....
20	.....	.....	2.25	2.40	3.15	3.00	1.70	1.10	1.10	1.90	2.10	.....
21	.....	.....	2.30	2.40	3.15	2.90	1.70	1.00	1.20	2.00	2.05	.....
22	.....	.....	2.30	2.55	3.10	2.90	1.60	1.00	1.55	2.00	2.00	.....
23	.....	.....	2.35	2.60	3.10	2.90	1.60	1.00	2.25	2.00	2.05	.....
24	.....	.....	2.55	2.60	3.10	2.80	1.50	1.05	2.30	2.00	2.10	.....
25	.....	.....	2.60	2.60	3.10	2.65	1.40	1.10	2.15	2.00	2.10	.....
26	.....	.....	2.65	2.50	3.05	2.60	1.40	1.00	1.95	2.00	2.20	.....
27	.....	.....	2.50	2.60	3.00	2.60	1.45	1.00	1.95	2.00	2.60	.....
28	.....	.....	2.45	2.60	2.90	2.50	1.65	1.10	2.00	2.00	2.50	.....
29	.....	.....	2.30	2.60	2.90	2.50	1.80	1.20	2.00	1.90	2.40	.....
30	.....	.....	2.05	2.60	2.90	2.70	1.65	1.10	1.90	1.90	2.20	.....
31	.....	.....	2.00	.....	2.80	.....	1.50	1.10	.....	2.00	.....	.....
1903.												
1	.....	.....	.....	2.40	2.70	2.70	3.15	2.00	1.75	1.85	2.00	2.40
2	.....	.....	.....	2.30	2.75	2.60	3.05	1.90	1.60	1.90	2.10	2.40
3	.....	.....	.....	2.35	2.85	2.55	3.10	1.85	1.55	1.90	2.10	2.25
4	.....	.....	.....	2.45	2.90	2.50	3.20	1.75	1.50	2.00	2.10	2.20
5	.....	.....	.....	2.50	2.90	2.45	3.10	1.65	1.50	2.00	2.10	2.05
6	.....	.....	.....	2.40	3.00	2.50	3.00	1.60	1.60	2.00	2.10	2.05
7	.....	.....	.....	2.40	2.90	2.50	2.85	1.50	1.60	2.00	2.05	1.85
8	.....	.....	.....	2.45	2.85	2.55	2.80	1.45	1.55	1.90	2.05	2.00
9	.....	.....	.....	2.70	2.75	2.60	2.75	1.45	1.60	1.95	2.10	2.10
10	.....	.....	.....	2.70	2.80	2.75	2.65	1.40	1.65	1.90	2.10	2.10
11	.....	.....	.....	2.65	2.75	2.85	2.60	1.85	1.55	1.90	2.10	2.30
12	.....	.....	.....	2.60	2.80	2.90	2.70	1.80	1.55	1.85	2.10	2.05
13	.....	.....	.....	2.55	2.65	2.90	2.55	1.80	1.40	1.95	2.10	2.20
14	.....	.....	.....	2.50	2.65	3.00	2.50	1.80	1.40	2.00	2.10	2.25
15	.....	.....	3.65	2.50	2.60	3.00	2.45	1.70	1.55	2.00	2.10	2.30
16	.....	.....	3.70	2.55	2.70	3.10	2.40	1.60	1.60	2.00	2.05	2.40
17	.....	.....	3.55	2.55	2.70	3.20	2.35	1.65	1.60	2.05	1.55	2.50
18	.....	.....	3.55	2.60	2.70	3.20	2.30	1.75	1.70	2.05	1.65	2.50
19	.....	.....	3.45	2.50	2.75	3.30	2.40	1.90	1.70	1.95	2.05	2.50
20	.....	.....	3.40	2.60	2.85	3.30	2.30	1.75	1.70	1.95	2.20	2.50
21	.....	.....	3.10	2.60	2.85	3.40	2.25	1.60	1.70	1.95	2.25	2.50
22	.....	.....	2.80	2.60	2.90	3.40	2.40	1.60	1.70	1.90	2.35	2.60
23	.....	.....	2.65	2.60	2.90	3.40	2.15	1.60	1.65	2.00	2.50	2.60
24	.....	.....	2.55	2.55	2.90	3.40	2.05	1.70	1.70	2.00	2.65	2.60
25	.....	.....	2.60	2.55	3.00	3.55	2.15	1.70	1.70	2.00	2.75	2.60
26	.....	.....	2.45	2.65	3.05	3.50	2.00	1.70	1.65	2.00	2.80	2.60
27	.....	.....	2.60	2.60	3.00	3.40	1.85	2.05	1.65	2.00	2.75	2.70
28	.....	.....	2.55	2.50	2.95	3.35	1.70	1.75	1.75	2.00	2.40	2.70
29	.....	.....	2.50	2.65	2.80	3.25	1.70	1.95	1.80	2.00	2.40	2.65
30	.....	.....	2.40	2.85	2.80	3.15	1.85	2.00	1.85	2.00	2.40	2.65
31	.....	.....	2.45	.....	2.80	.....	1.90	1.80	.....	2.00	.....	2.70
1904.												
1	2.70	.....	2.80	2.40	2.60	3.50	2.83	1.73	1.32	2.12	2.02	2.22
2	2.50	.....	2.50	2.30	2.60	3.55	2.85	1.75	1.78	2.08	1.98	2.25
3	2.45	.....	1.50	2.30	2.58	3.65	2.98	1.90	1.48	1.98	1.95	2.25
4	2.50	.....	1.60	2.30	2.75	3.57	2.88	1.95	1.62	1.92	1.95	2.08
5	2.65	.....	1.60	2.30	2.85	3.43	2.80	1.77	1.48	1.75	1.98	2.05
6	2.70	.....	2.20	2.30	2.78	3.33	2.95	2.20	1.35	1.75	2.00	2.10
7	2.70	.....	2.35	2.00	2.63	3.30	3.13	1.85	1.30	1.78	2.00	2.12
8	2.65	.....	2.40	2.50	2.63	3.28	2.97	1.80	1.18	1.70	1.98	2.20
9	2.75	.....	2.60	2.10	3.03	3.45	3.00	1.67	1.12	1.82	1.90	2.22
10	2.80	.....	2.55	2.25	3.03	3.57	2.80	1.60	1.05	1.80	1.90	2.30
11	2.80	.....	2.45	2.10	2.93	3.60	2.92	1.55	1.05	1.78	1.92	2.30
12	2.80	.....	2.30	1.95	2.83	3.55	2.80	1.43	1.08	1.78	2.00	2.30
13	2.80	.....	2.35	2.10	2.80	3.85	2.73	1.44	1.05	1.62	2.15	2.55
14	2.80	.....	2.50	2.15	2.78	3.92	2.70	1.35	1.05	1.62	2.08	2.60
15	2.80	.....	2.50	2.10	2.73	3.75	2.68	1.30	1.08	1.62	1.98	.....
16	2.90	.....	2.40	1.95	2.68	3.75	2.50	1.27	1.05	1.65	2.02	.....
17	2.90	.....	2.40	2.05	2.75	3.60	2.40	1.23	1.05	1.65	2.15	.....
18	2.90	.....	2.35	2.00	2.75	3.50	2.35	1.25	1.05	1.85	2.10	.....
19	2.85	.....	2.25	1.85	2.68	3.50	2.25	1.25	1.00	2.08	2.10	.....
20	2.70	.....	2.30	1.90	2.68	3.45	2.40	1.20	.95	2.02	2.02	.....

Mean daily gage height, in feet, of North Platte River at North Platte, 1895–1906—Con.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.												
21	2.70	.....	2.30	1.95	2.73	3.45	2.27	1.15	1.08	1.98	2.00	.....
22	2.80	.....	2.35	2.05	2.80	3.40	2.20	1.12	1.08	1.90	2.00	.....
23	2.80	.....	2.50	1.95	2.80	3.45	2.22	1.10	1.15	1.82	2.05	.....
24	2.80	.....	2.40	1.95	2.85	3.38	2.25	1.05	1.08	1.92	2.12	.....
25	2.80	.....	2.20	1.90	2.85	3.33	2.10	1.10	1.08	2.10	2.15	.....
26	2.75	.....	2.20	2.20	3.58	3.25	2.05	1.10	1.08	2.10	2.10	.....
27	2.65	.....	2.30	2.30	3.35	3.15	2.00	1.10	1.15	2.08	2.08	.....
28	2.60	3.75	2.40	2.30	3.25	3.05	1.95	1.10	1.40	2.08	2.05	.....
29	2.70	3.30	2.20	2.35	3.25	3.05	2.02	1.20	1.48	2.08	2.00	.....
30	2.55	.....	2.25	2.45	3.30	3.05	1.80	1.18	1.80	2.10	2.05	.....
31	.....	.....	2.40	.....	3.30	.....	1.75	1.20	.....	2.05	.....	.....
1905.												
1	.....	.....	.....	2.58	3.18	3.65	3.4	2.52	1.6	1.48	.....	.....
2	.....	.....	.....	2.62	3.32	3.88	3.65	2.48	1.55	1.5	.....	.....
3	.....	.....	.....	2.65	3.45	3.88	3.68	2.45	1.5	1.55	.....	.....
4	.....	.....	.....	2.75	3.38	3.88	3.38	2.3	1.52	1.55	.....	.....
5	.....	.....	2.85	2.7	3.38	3.68	3.28	2.22	1.62	1.58	.....	.....
6	.....	.....	2.75	2.62	3.4	3.58	3.38	2.22	1.7	1.65	.....	.....
7	.....	.....	2.02	2.48	3.45	3.5	3.18	2.18	1.72	1.65	.....	.....
8	.....	.....	2.5	2.38	3.48	3.48	3.1	2.15	1.7	1.65	.....	.....
9	.....	.....	2.4	2.25	3.5	3.52	3.0	2.18	1.7	1.6	.....	.....
10	.....	.....	2.45	2.28	3.4	3.72	2.9	2.1	1.72	1.65	.....	.....
11	.....	.....	2.5	2.38	3.48	3.88	2.82	2.05	1.7	1.72	.....	.....
12	.....	.....	2.4	2.35	3.5	4.02	2.8	2.0	1.65	1.72	.....	.....
13	.....	.....	2.4	2.42	3.5	3.95	2.75	2.2	1.65	1.65	.....	.....
14	.....	.....	2.5	2.45	3.55	3.9	2.62	2.2	1.75	1.65	.....	.....
15	.....	.....	2.42	2.5	3.4	4.08	2.52	2.18	1.85	1.82	.....	.....
16	.....	.....	2.68	2.45	3.35	4.28	2.42	2.02	1.68	1.78	.....	.....
17	.....	.....	2.82	2.45	3.2	4.08	2.32	2.0	1.58	1.72	.....	.....
18	.....	.....	2.7	2.48	3.18	3.9	2.2	1.92	1.68	1.78	.....	.....
19	.....	.....	2.82	2.45	3.18	3.8	2.28	1.95	1.82	1.8	.....	.....
20	.....	.....	2.65	2.42	3.28	3.75	2.42	2.02	1.9	1.9	.....	.....
21	.....	.....	2.5	2.8	3.2	3.6	2.5	1.85	1.8	1.9	.....	.....
22	.....	.....	2.4	2.8	3.1	3.6	2.42	1.8	1.75	1.9	.....	.....
23	.....	.....	2.32	2.72	3.05	3.62	2.28	1.75	1.8	1.85	.....	.....
24	.....	.....	2.28	2.9	3.1	3.62	2.28	1.68	1.72	1.9	.....	.....
25	.....	.....	2.28	3.12	3.28	3.42	2.3	1.68	1.68	1.98	.....	.....
26	.....	.....	2.25	3.1	3.28	3.32	2.18	1.7	1.62	1.9	.....	.....
27	.....	.....	2.25	3.0	3.82	3.28	2.2	1.68	1.58	1.9	.....	.....
28	.....	.....	2.38	2.9	3.65	3.18	2.18	1.65	1.55	2.0	.....	.....
29	.....	.....	2.4	3.05	3.78	3.12	2.38	1.6	1.6	2.05	.....	.....
30	.....	.....	2.38	3.22	3.7	3.22	2.1	1.75	1.6	2.02	.....	.....
31	.....	.....	2.4	.....	3.65	.....	2.18	1.72	.....	2.0	.....	.....
1906.												
1	.....	.....	.....	.....	2.95	3.70	2.88	2.08	2.05	1.92	2.35	.....
2	.....	.....	.....	.....	2.90	3.75	2.88	2.05	2.05	1.95	2.32	.....
3	.....	.....	.....	.....	2.95	3.78	2.90	1.92	2.02	1.95	2.55	.....
4	.....	.....	.....	.....	2.88	3.78	2.82	1.85	2.00	1.90	2.50	.....
5	.....	.....	.....	.....	2.92	3.98	2.80	1.88	2.00	1.90	2.40	.....
6	.....	.....	.....	.....	2.88	3.85	2.70	2.20	1.88	1.88	2.38	.....
7	.....	.....	.....	.....	2.70	3.80	2.60	2.38	1.78	1.85	2.35	.....
8	.....	.....	.....	.....	2.62	3.35	2.50	2.10	1.72	1.82	2.32	.....
9	.....	.....	.....	.....	2.60	3.20	2.48	1.95	1.70	1.90	2.32	.....
10	.....	.....	.....	2.80	2.60	3.05	2.45	1.85	1.70	1.90	2.38	.....
11	.....	.....	.....	2.78	2.62	3.02	2.45	1.80	1.85	1.90	2.40	.....
12	.....	.....	.....	2.88	2.60	3.10	2.40	1.70	2.08	1.90	2.40	.....
13	.....	.....	.....	3.00	2.65	3.10	2.42	1.62	2.00	1.90	2.30	.....
14	.....	.....	.....	2.80	2.65	3.15	2.50	1.55	2.00	2.00	2.30	.....
15	.....	.....	.....	2.75	2.75	3.10	2.45	1.60	1.88	2.00	2.25	.....
16	.....	.....	.....	2.68	2.85	3.10	2.35	1.60	1.70	1.95	2.28	.....
17	.....	.....	.....	2.70	2.78	2.92	2.22	1.52	1.78	1.98	2.25	.....
18	.....	.....	.....	2.68	2.78	2.80	2.28	1.48	1.85	1.92	2.20	.....
19	.....	.....	.....	2.82	2.92	2.90	2.32	1.42	1.85	1.95	2.20	.....
20	.....	.....	.....	2.88	3.00	2.98	2.38	1.30	2.02	1.98	2.02	.....
21	.....	.....	.....	2.80	3.18	3.12	2.42	1.20	2.02	1.85	1.85	.....
22	.....	.....	.....	2.75	3.06	3.20	2.60	1.08	2.00	2.12	1.85	.....
23	.....	.....	.....	2.70	3.05	3.18	2.52	1.82	2.00	2.45	1.98	.....
24	.....	.....	.....	2.72	3.08	3.25	2.40	2.10	1.98	2.15	2.10	.....
25	.....	.....	.....	2.68	3.32	3.22	2.42	1.88	2.00	2.05	2.28	.....

Mean daily gage height, in feet, of North Platte River at North Platte, 1895–1906—Con.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906.												
26	.....	.....	.....	2.55	3.20	3.12	2.40	1.95	1.92	2.18	2.35	.....
27	.....	.....	.....	2.75	3.20	3.15	2.45	1.78	1.90	2.35	2.25	.....
28	.....	.....	.....	2.95	3.20	3.05	2.30	1.68	1.90	2.75	2.20	.....
29	.....	.....	.....	2.82	3.22	2.95	2.20	1.65	1.88	2.85	2.20	.....
30	.....	.....	.....	2.75	3.35	2.90	2.10	1.85	1.90	2.50	2.38	.....
31	.....	.....	.....	.....	3.52	.....	2.10	2.10	.....	2.38	.....	.....

Mean daily discharge, in second-feet, of North Platte River at North Platte, 1895–1906.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1895.										
1	10,180	1,723	5,191	9,735	5,191	628	323	272	1,095	.....
2	8,060	2,512	5,848	8,464	4,575	537	323	200	963	.....
3	4,878	1,551	5,848	8,060	3,725	963	323	231	1,095	.....
4	4,878	1,551	8,464	12,553	4,282	730	200	384	1,389	.....
5	4,878	1,905	9,735	12,553	4,575	537	200	384	1,551	.....
6	4,282	2,968	10,635	12,058	3,998	628	200	384	1,389	.....
7	3,210	3,463	10,635	16,875	3,998	842	150	384	1,095	.....
8	4,575	3,210	8,878	15,732	4,575	842	150	537	1,095	.....
9	2,968	2,300	6,908	15,732	5,191	628	175	730	1,389	.....
10	1,723	1,551	7,282	15,177	5,848	628	175	730	963	.....
11	3,463	2,735	7,282	14,632	5,191	628	175	537	1,095	.....
12	2,968	2,735	6,191	12,553	4,575	628	175	842	1,237	.....
13	963	2,968	5,541	11,573	3,998	537	200	730	1,905	.....
14	537	2,512	4,878	12,553	3,998	384	200	842	1,551	.....
15	455	1,723	5,848	11,573	3,463	455	175	842	1,551	.....
16	1,389	2,512	5,848	11,573	2,968	628	272	1,095	1,551	.....
17	1,725	3,210	6,908	12,550	2,098	455	272	1,095	1,237	.....
18	2,300	3,725	8,060	10,635	1,551	384	200	1,095	1,389	.....
19	2,512	3,463	6,544	10,635	1,551	323	200	963	1,237	.....
20	2,968	2,968	6,908	9,735	1,905	384	150	842	1,389	.....
21	2,300	4,282	6,544	8,878	1,551	272	200	842	963	.....
22	2,098	5,191	6,908	10,180	1,723	231	231	842	1,095	.....
23	2,098	5,191	6,908	8,878	2,098	272	455	1,095	1,237	.....
24	2,300	4,878	7,282	8,878	2,968	231	384	1,095	1,551	.....
25	2,300	4,878	6,544	8,464	2,968	272	323	1,237	1,905	.....
26	3,463	4,281	6,191	7,665	2,098	200	272	1,237	1,905	.....
27	2,512	5,191	6,191	7,665	1,551	175	272	1,389	1,551	.....
28	2,300	5,848	5,848	7,282	5,551	537	200	1,095	1,551	.....
29	2,098	6,544	5,191	6,191	1,389	455	231	1,095	1,237	.....
30	1,723	6,544	7,280	5,848	1,237	384	323	842	1,551	.....
31	1,389	.....	9,735	.....	842	323	.....	1,237	.....	.....
1896.										
1	.....	.....	3,225	3,392	2,680	1,600	550	1,240	3,460	.....
2	.....	.....	3,392	4,000	2,680	1,475	738	960	3,720	.....
3	.....	.....	3,048	3,392	2,335	1,730	637	840	2,960	.....
4	.....	.....	3,780	2,680	2,020	1,860	637	730	2,300	.....
5	.....	.....	4,555	14,613	1,730	1,240	600	840	2,090	.....
6	.....	.....	6,777	16,300	1,600	1,475	600	730	1,240	.....
7	.....	.....	5,655	14,613	1,475	1,730	550	1,090	960	.....
8	.....	.....	6,777	12,927	1,130	1,240	550	1,240	730	.....
9	.....	.....	5,111	11,241	1,130	800	600	1,090	1,090	.....
10	.....	1,860	4,000	10,117	950	950	675	1,240	1,390	.....
11	.....	2,335	4,000	9,000	800	675	800	960	1,720	.....
12	.....	3,048	3,780	9,000	600	600	800	1,090	1,900	.....
13	.....	3,560	4,555	9,000	550	600	950	1,090	2,300	.....
14	.....	3,048	5,655	7,333	460	550	1,130	1,090	1,900	.....
15	.....	2,680	7,888	5,655	320	520	1,130	1,090	2,090	.....
16	.....	2,490	5,655	4,000	350	460	950	1,240	1,720	.....
17	.....	2,870	5,655	3,780	280	520	800	1,240	2,510	.....
18	.....	2,870	6,222	3,780	250	637	875	960	2,510	.....
19	.....	2,490	5,111	5,111	350	800	950	960	2,960	.....
20	.....	2,680	5,655	4,000	405	875	875	960	1,240	.....
21	.....	3,225	5,655	3,780	575	1,130	875	960	1,550	.....
22	.....	2,680	5,111	3,560	875	950	950	1,240	1,090	.....
23	.....	3,048	4,000	3,225	1,600	800	800	1,550	1,390	.....
24	.....	2,680	4,000	3,560	2,335	950	875	1,240	2,090	.....
25	.....	3,225	3,780	4,555	1,240	738	950	1,240	2,510	.....

Mean daily discharge, in second-feet, of North Platte River at North Platte, etc.—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1896.										
26	.....	3,048	3,560	3,780	1,040	600	1,130	1,240	2,730	.....
27	.....	2,680	3,225	3,560	875	550	1,130	1,240	3,200	.....
28	.....	2,683	3,225	3,560	675	600	1,200	960	3,200	.....
29	.....	3,048	2,680	4,000	1,350	575	1,200	1,390	3,200	.....
30	.....	3,048	2,680	2,680	1,040	550	1,130	1,390	3,200	.....
31	.....	.....	2,870	.....	1,475	600	.....	2,510	.....	.....
1897.										
1	2,341	2,645	8,231	21,527	6,197	1,090	850	615	2,624	.....
2	3,689	3,515	7,812	20,296	5,716	1,090	850	486	1,510	.....
3	4,457	4,457	8,650	20,796	5,556	1,090	743	486	963	.....
4	5,296	4,457	11,854	18,603	5,235	1,510	679	486	743	.....
5	5,712	5,296	11,854	18,603	4,914	2,306	615	486	743	.....
6	6,554	4,038	10,328	18,603	4,754	4,593	679	486	963	.....
7	6,973	4,457	11,854	21,527	4,432	4,432	550	486	1,510	.....
8	7,392	5,296	11,854	23,720	4,272	4,754	422	486	1,510	.....
9	7,812	4,457	14,948	21,849	4,593	432	422	486	2,624	.....
10	8,650	3,863	14,217	17,172	4,112	593	486	679	2,624	.....
11	9,489	3,863	14,217	16,637	3,174	754	679	550	1,510	.....
12	3,167	4,896	14,948	16,637	3,409	272	743	679	1,510	.....
13	3,341	3,863	14,948	13,490	4,272	3,643	615	743	1,510	.....
14	2,993	3,515	14,217	11,916	3,174	4,112	679	679	1,510	.....
15	2,645	3,167	14,948	9,768	2,940	4,593	615	473	1,510	.....
16	2,471	2,471	10,328	11,393	3,409	4,272	679	963	1,510	.....
17	2,993	2,471	13,486	11,393	3,409	4,272	679	1,090	2,624	.....
18	3,515	2,645	10,328	12,442	3,643	4,272	743	1,343	2,624	.....
19	2,471	2,645	10,328	11,393	3,409	4,112	615	1,510	2,624	.....
20	2,296	2,819	13,486	11,390	4,272	3,643	615	963	2,624	.....
21	3,167	3,515	11,854	11,393	3,409	3,643	615	963	2,624	.....
22	3,167	3,863	13,486	11,393	3,878	4,309	615	743	2,306	.....
23	2,993	5,296	13,486	11,393	4,432	2,306	550	743	2,624	.....
24	2,645	6,973	14,217	9,768	2,940	1,510	486	743	2,624	.....
25	2,122	8,650	15,679	9,768	2,940	1,090	550	743	963	.....
26	1,774	10,328	17,872	7,331	2,306	1,090	550	1,090	2,306	.....
27	2,296	13,486	20,063	6,518	2,306	963	486	1,510	3,409	.....
28	1,948	9,489	20,796	7,331	2,306	963	486	3,643	4,112	.....
29	1,774	8,650	20,796	6,518	2,306	850	486	3,878	4,112	.....
30	2,122	8,231	21,527	6,518	1,510	743	486	3,643	4,112	.....
31	2,296	.....	20,796	.....	1,090	743	.....	2,940	.....	.....
1898.										
1	3,138	3,138	3,785	12,034	4,217	548	150	324	697	2,275
2	2,707	2,707	4,001	9,559	4,001	1,270	70	289	697	2,275
3	2,064	2,491	4,433	8,785	4,001	1,413	90	254	697	2,275
4	2,064	2,064	4,433	8,528	4,433	840	90	289	697	2,707
5	1,844	2,707	4,433	8,270	3,785	510	120	289	984	2,707
6	1,700	3,138	4,433	7,786	3,570	473	80	324	984	2,707
7	1,700	2,707	4,648	7,786	3,354	548	100	324	984	2,707
8	2,064	2,922	4,433	7,817	2,491	473	160	324	697	2,707
9	2,491	2,491	4,433	6,817	2,275	399	219	436	984	2,707
10	2,491	1,700	4,433	6,817	3,570	324	324	399	660	2,707
11	2,491	2,064	4,001	6,817	2,707	306	436	399	697	3,570
12	2,491	2,491	4,001	6,817	3,138	289	660	436	984	3,570
13	2,275	2,707	3,785	6,333	1,844	254	548	399	984	3,570
14	2,064	2,275	3,570	8,270	1,557	219	697	399	984	3,570
15	2,491	1,844	3,785	7,302	1,270	178	984	399	697	3,570
16	2,064	2,275	4,217	6,333	984	179	697	399	1,127	3,570
17	2,275	1,557	6,817	5,848	1,127	179	660	399	984	3,570
18	1,844	1,700	5,296	6,333	984	179	548	399	2,270	.....
19	2,491	1,700	4,864	6,817	984	160	473	473	1,844	.....
20	2,491	2,064	4,864	7,302	697	100	399	548	1,557	.....
21	2,707	2,064	5,296	6,817	697	100	362	548	1,127	.....
22	2,064	2,064	5,080	5,848	697	100	324	548	984	.....
23	1,557	2,491	5,296	5,842	715	254	324	622	984	.....
24	1,551	2,275	4,864	5,848	622	271	324	622	984	.....
25	1,413	2,491	4,864	5,848	660	199	324	622	984	.....
26	1,270	2,922	5,296	5,296	622	160	324	660	984	.....
27	1,700	3,785	6,817	5,296	622	140	324	697	984	.....
28	2,491	3,785	6,817	5,080	510	90	289	697	1,844	.....
29	3,354	3,785	5,848	4,433	399	120	289	697	1,557	.....
30	2,922	3,785	14,646	4,648	324	90	306	697	1,557	.....
31	2,707	.....	10,074	.....	473	80	.....	697	.....	.....

Mean daily discharge, in second-feet, of North Platte River at North Platte, etc.—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1899.										
1	7,440	3,831	10,591	10,961	15,428	5,197	2,215	976	1,270	.....
2	7,440	3,023	10,591	12,146	16,257	5,757	1,845	850	1,557	.....
3	7,440	6,317	9,851	12,962	15,839	5,757	1,845	875	1,557	.....
4	7,440	5,757	8,837	12,962	15,428	6,317	1,845	713	1,700	.....
5	7,440	5,197	8,277	12,146	15,428	6,317	1,322	713	1,844	.....
6	7,440	6,317	7,437	11,330	15,428	8,557	1,322	713	2,059	.....
7	7,440	6,597	7,437	11,738	14,606	5,477	1,495	713	1,844	.....
8	7,440	4,917	8,837	12,962	14,606	4,637	1,495	622	1,844	.....
9	7,440	4,637	8,277	13,782	14,606	4,637	1,149	622	1,844	.....
10	8,000	4,637	6,317	13,782	14,606	4,235	1,019	622	1,844	.....
11	8,000	4,637	6,037	13,373	13,784	3,831	1,149	622	1,844	.....
12	8,000	5,197	5,197	12,554	11,738	3,831	1,149	713	1,844	.....
13	8,000	5,477	5,197	11,738	11,330	4,033	1,149	713	1,557	.....
14	8,000	4,637	4,637	10,961	11,330	4,637	1,149	667	1,557	.....
15	8,000	4,437	5,197	11,330	10,961	4,637	1,019	984	1,700	.....
16	8,000	4,637	5,477	12,146	9,851	4,235	889	984	1,844	.....
17	7,420	8,837	6,397	14,195	9,111	4,033	889	984	1,700	.....
18	6,320	9,111	7,717	14,606	8,557	4,235	889	984	1,557	.....
19	6,320	9,481	7,717	16,257	8,837	3,831	889	984	1,844	.....
20	6,320	9,851	9,851	15,838	9,111	3,831	889	984	1,844	.....
21	4,640	9,111	11,350	14,195	9,111	3,831	875	984	2,275	.....
22	6,320	7,997	12,554	13,373	8,557	2,619	875	984	2,275	.....
23	6,320	7,997	12,554	13,784	8,277	2,619	850	984	1,844	.....
24	7,720	7,997	12,967	13,373	7,437	2,215	850	984	1,844	.....
25	6,880	7,437	12,146	15,839	7,157	2,215	850	984	1,844	.....
26	5,200	6,877	12,962	17,072	6,317	2,215	875	1,270	1,844	.....
27	5,200	7,437	13,373	18,305	6,317	2,215	875	1,557	1,844	.....
28	4,920	7,437	13,373	17,894	6,597	2,030	976	1,557	2,275	.....
29	4,640	7,437	12,554	17,072	5,757	1,668	875	1,557	1,844	.....
30	4,920	7,997	10,591	16,661	5,757	1,322	875	1,557	1,844	.....
31	5,200	.....	10,591	.....	4,917	1,668	.....	413	.....	.....
1900.										
1	4,050	2,150	7,800	10,500	5,025	1,035	70	465	950	.....
2	5,025	2,150	7,350	11,100	3,440	875	70	465	950	.....
3	6,100	1,800	9,350	11,100	3,440	670	70	465	950	.....
4	6,900	1,975	8,800	13,500	3,440	515	70	465	950	.....
5	6,900	2,150	9,350	16,000	5,350	565	70	370	800	.....
6	6,900	2,520	11,100	16,850	4,700	950	70	370	800	.....
7	4,700	2,950	11,100	16,850	4,700	2,150	70	370	875	.....
8	4,700	3,440	9,900	17,700	3,745	1,220	70	370	950	.....
9	4,700	2,950	8,300	16,000	2,735	1,220	70	370	950	.....
10	4,375	2,950	7,800	15,150	1,800	735	125	370	800	.....
11	2,950	3,195	7,800	14,300	1,680	670	100	370	875	.....
12	2,150	3,440	7,800	12,700	1,560	670	100	370	1,035	.....
13	1,680	3,745	8,300	11,100	1,800	565	100	465	950	.....
14	1,320	3,440	8,800	11,100	1,560	515	70	465	1,035	.....
15	2,520	4,050	8,800	11,900	1,560	370	70	465	1,120	.....
16	4,700	5,350	8,800	12,700	1,680	370	100	465	1,035	.....
17	2,150	5,350	8,800	12,700	1,560	325	100	465	950	.....
18	1,516	5,350	10,500	12,700	1,440	245	125	565	875	.....
19	1,320	4,700	14,300	10,500	1,120	210	125	565	670	.....
20	2,520	4,050	14,300	8,800	1,320	125	125	565	800	.....
21	2,950	3,745	11,100	8,800	1,320	515	100	565	1,220	.....
22	2,520	4,050	11,100	7,800	1,320	565	100	565	1,220	.....
23	2,950	4,700	10,500	6,900	1,560	415	100	670	1,320	.....
24	2,735	5,350	9,900	6,900	2,335	565	100	800	1,220	.....
25	2,520	6,100	9,900	6,900	2,335	515	100	670	1,800	.....
26	2,520	6,900	9,350	6,100	2,950	465	100	670	1,975	.....
27	2,150	6,900	8,800	5,350	2,335	280	150	670	2,150	.....
28	2,150	6,500	8,300	5,350	1,320	280	210	670	1,680	.....
29	1,975	5,350	7,800	4,700	1,320	150	210	735	1,320	.....
30	2,150	5,725	7,800	4,700	1,320	150	325	800	1,320	.....
31	.....	.....	9 900	.....	1,120	100	.....	875	.....	.....
1901.										
1	.....	3,440	2,150	9,900	4,050	210	1,120	670	1,320	.....
2	.....	3,440	58450	8,800	3,440	210	1,320	670	1,320	.....
3	.....	3,440	6,900	7,800	3,440	150	1,120	670	1,320	.....
4	.....	2,520	6,100	7,800	3,440	100	1,320	670	1,320	.....
5	.....	1,800	6,900	9,900	2,950	75	1,320	800	1,320	.....

Mean daily discharge, in second-feet, of North Platte River at North Platte, etc.—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1901.										
6	4,050	2,150	6,900	11,100	2,950	75	1,320	800	1,320	.....
7	2,150	2,150	6,900	11,100	2,950	50	1,320	1,120	1,320	.....
8	2,950	1,560	6,100	12,700	2,520	75	1,320	1,120	1,320	.....
9	2,950	1,560	6,100	12,700	2,520	100	1,320	950	1,320	.....
10	2,520	2,150	6,100	12,700	2,150	100	1,320	1,320	1,320	.....
11	2,950	3,440	6,900	12,700	1,800	210	1,560	1,320	1,320	.....
12	2,150	4,700	6,100	17,700	1,800	465	1,800	1,320	1,560	.....
13	1,800	4,050	6,100	9,900	1,800	465	1,800	950	1,560	.....
14	1,800	2,950	6,100	11,100	1,320	370	1,320	1,120	1,560	.....
15	2,150	2,950	6,100	11,100	1,320	280	1,120	1,120	1,560	.....
15	1,800	2,520	6,100	11,100	950	370	950	1,120	1,800	.....
17	1,800	2,520	5,450	11,100	943	370	800	1,120	1,800	.....
18	1,800	2,520	5,450	9,900	950	370	800	1,120	1,800	.....
19	2,950	2,150	5,450	8,800	950	370	1,120	1,120	1,800	.....
20	1,800	2,150	5,450	12,700	950	280	1,120	1,120	1,800	.....
21	1,800	2,150	6,100	9,900	670	670	1,120	1,320	1,800	.....
22	1,800	1,800	6,100	7,800	465	800	800	1,320	1,800	.....
23	1,800	1,800	9,900	9,900	280	565	670	1,320	1,800	.....
24	1,800	1,800	11,100	8,800	210	465	670	1,320	1,800	.....
25	1,560	1,560	11,100	7,800	150	370	670	1,320	1,800	.....
26	1,560	1,560	12,700	6,900	565	370	670	1,320	1,800	.....
27	1,800	1,560	12,700	6,100	465	370	565	1,320	1,800	.....
29	1,320	1,560	14,300	5,450	370	370	565	1,320	1,800	.....
29	1,320	2,150	14,300	4,700	100	465	565	1,320	1,560	.....
30	1,800	2,150	11,100	4,050	75	800	565	1,320	1,560	.....
31	7,800	.....	9,900	.....	210	800	.....	1,320	.....	.....
1902.										
1	.....	1,320	4,050	3,440	6,100	370	150	950	1,120	.....
2	.....	1,800	4,050	3,440	5,450	280	150	950	1,120	.....
3	.....	2,150	3,440	3,158	4,991	150	150	950	1,120	.....
4	.....	2,520	3,440	2,950	4,050	100	100	950	1,120	.....
5	.....	2,520	4,050	2,950	3,440	100	100	1,120	1,120	.....
6	.....	2,520	3,723	4,050	4,050	75	100	1,120	1,120	.....
7	.....	1,804	3,440	5,450	4,050	50	100	950	1,120	.....
8	.....	1,800	3,440	5,450	3,440	50	100	800	1,120	.....
9	.....	1,800	3,440	6,100	4,050	55	100	800	1,120	.....
10	.....	1,800	3,440	5,450	3,440	50	100	670	1,120	.....
11	.....	1,560	3,440	4,700	3,440	50	100	1,120	1,120	.....
12	.....	1,320	4,700	6,900	2,950	30	150	1,120	1,120	.....
13	.....	1,320	5,450	6,100	2,520	30	150	1,120	1,120	.....
14	.....	1,800	5,450	6,900	2,150	50	150	1,120	1,120	.....
15	.....	2,150	6,100	6,900	2,520	50	210	1,120	1,320	.....
16	950	2,520	9,900	6,900	1,320	50	210	1,120	1,320	.....
17	1,320	2,520	7,800	6,100	1,293	30	150	1,120	1,320	.....
18	1,800	2,520	6,900	6,900	1,120	49	210	1,120	1,320	.....
19	1,800	2,520	6,900	6,610	1,120	100	210	950	1,320	.....
20	2,150	2,520	7,136	6,900	950	100	150	950	1,120	.....
21	2,150	2,520	7,800	6,100	800	75	280	1,120	950	.....
22	2,150	2,950	6,900	6,100	670	75	565	1,120	800	.....
23	2,520	3,440	6,900	6,100	670	94	1,800	1,120	800	.....
24	3,440	3,440	6,900	5,450	565	100	1,783	1,120	800	.....
25	3,440	3,440	6,900	4,050	465	150	1,320	1,120	800	.....
26	4,050	2,950	6,100	4,050	370	100	1,320	1,120	950	.....
27	2,950	3,440	6,100	3,050	465	100	1,320	1,120	1,560	.....
28	2,950	3,440	5,450	3,440	694	150	1,120	1,120	1,120	.....
29	1,800	3,440	5,450	3,440	800	210	1,120	950	845	.....
30	1,320	3,440	5,450	4,050	800	150	950	950	.....	.....
31	1,320	.....	4,700	.....	370	150	.....	1,120	.....	.....
1903.										
1	.....	2,520	4,050	4,050	8,300	1,035	670	875	1,220	.....
2	.....	2,150	4,375	3,440	7,350	875	515	950	1,440	.....
3	.....	2,335	5,025	3,195	7,350	800	465	950	1,440	.....
4	.....	2,735	5,350	2,950	8,300	670	415	1,120	1,440	.....
5	.....	2,950	5,350	2,735	7,350	565	415	1,120	1,440	.....
6	.....	2,520	6,100	2,950	6,500	565	515	1,120	1,440	.....
7	.....	2,520	5,350	2,950	5,350	465	515	1,120	1,320	.....
8	.....	2,735	5,025	3,195	4,700	415	465	950	1,320	.....
9	.....	4,050	4,375	3,440	4,375	415	515	1,035	1,440	.....
10	.....	4,050	4,700	4,375	3,745	370	565	950	1,440	.....

Mean daily discharge, in second-feet, of North Platte River at North Platte, etc.—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1903.										
11	.....	3,745	4,375	5,025	3,440	875	465	950	1,440	.....
12	.....	3,440	4,700	5,350	4,050	800	465	875	1,440	.....
13	.....	3,195	3,745	5,350	3,195	800	325	1,035	1,440	.....
14	.....	2,950	3,745	6,100	2,950	800	325	1,120	1,440	.....
15	13,500	2,950	3,440	6,100	2,520	670	465	1,120	1,440	.....
16	14,300	3,195	4,050	6,900	2,335	565	515	1,120	1,320	.....
17	11,900	3,195	4,050	7,800	2,150	615	515	1,220	565	.....
18	11,900	3,440	4,050	7,800	1,975	735	615	1,220	670	.....
19	10,500	2,950	4,375	8,800	2,335	950	615	1,035	.....	.....
20	9,900	3,440	5,025	8,800	1,975	735	615	1,035	.....	.....
21	6,900	3,440	5,025	9,900	1,800	565	615	1,035	.....	.....
22	4,700	3,440	5,350	9,900	2,335	565	615	950	.....	.....
23	3,745	3,440	5,350	9,900	1,560	565	565	1,120	.....	.....
24	3,195	3,195	5,350	9,900	1,320	670	615	1,120	.....	.....
25	3,440	3,195	6,100	11,900	1,440	670	615	1,220	.....	.....
26	2,735	3,745	6,500	12,700	1,120	670	565	1,220	.....	.....
27	3,440	3,440	6,100	11,100	875	1,220	565	1,220	.....	.....
28	3,195	2,950	5,725	10,500	670	670	670	1,220	.....	.....
29	2,950	3,745	4,700	9,350	670	950	735	1,220	.....	.....
30	2,520	5,025	4,700	8,300	875	1,035	800	1,220	.....	.....
31	2,735	.....	4,700	.....	875	735	.....	1,220	.....	.....
1904.										
1	1,000	2,070	3,870	10,600	5,320	810	75	1,720	1,415	2,070
2	1,000	1,720	3,870	11,350	5,320	810	925	1,720	1,415	2,260
3	1,000	2,460	3,870	12,900	6,310	1,150	250	1,415	1,280	2,260
4	1,000	2,460	4,720	11,350	5,640	1,280	475	1,150	1,280	1,720
5	1,000	2,460	5,320	10,000	5,010	810	250	810	1,415	1,560
6	1,000	2,460	4,720	8,980	5,980	2,070	85	810	1,415	1,720
7	1,500	1,415	4,140	8,560	7,400	1,040	75	925	1,415	1,720
8	1,500	1,500	4,140	8,160	5,980	925	50	700	1,415	2,070
9	1,500	1,720	6,310	10,000	6,310	590	40	925	1,150	2,070
10	2,000	2,260	6,310	10,600	5,320	475	35	925	1,150	2,460
11	2,000	1,720	5,640	12,100	5,640	370	35	925	1,150	2,460
12	1,500	1,280	5,320	11,350	5,010	175	40	925	1,415	2,460
13	1,500	1,720	5,010	16,500	4,720	175	35	475	1,890	.....
14	1,500	1,890	5,010	17,500	4,420	85	35	475	1,720	.....
15	1,500	1,720	4,720	14,600	4,420	75	40	475	1,415	.....
16	1,500	1,280	4,420	14,600	3,360	65	35	590	1,415	.....
17	1,500	1,560	4,720	12,100	2,890	65	35	590	1,890	.....
18	1,500	1,415	4,720	10,600	2,680	65	35	1,040	1,720	.....
19	1,200	1,000	4,420	10,600	2,260	65	25	1,720	1,720	.....
20	1,200	1,150	4,420	10,000	2,890	50	20	1,415	1,415	.....
21	1,200	1,280	4,720	10,000	2,260	45	40	1,415	1,415	.....
22	1,200	1,560	5,010	9,400	2,070	40	40	1,150	1,415	.....
23	1,200	1,280	5,010	10,000	2,070	40	45	925	1,560	.....
24	1,200	1,280	5,320	9,400	2,260	35	40	1,150	1,720	.....
25	1,100	1,150	5,320	8,980	1,720	40	40	1,720	1,890	.....
26	1,150	2,070	11,350	8,160	1,560	40	40	1,720	1,720	.....
27	1,415	2,460	8,980	7,400	1,410	40	45	1,720	1,720	.....
28	1,720	2,460	8,160	6,660	1,280	40	100	1,720	1,560	.....
29	1,415	2,680	8,160	6,660	1,415	50	250	1,720	1,415	.....
30	1,415	3,130	8,560	6,660	925	50	925	1,720	1,560	.....
31	2,070	.....	8,560	.....	810	50	.....	1,560	.....	.....
1905.										
1	.....	3,172	7,848	13,355	11,870	4,330	530	200	.....	.....
2	.....	3,418	9,304	16,608	14,815	4,080	445	220	.....	.....
3	.....	3,610	10,800	16,608	15,184	3,900	360	250	.....	.....
4	.....	4,275	9,976	16,608	11,654	3,050	394	250	.....	.....
5	4,995	3,930	9,976	13,760	10,586	2,642	572	280	.....	.....
6	4,275	3,418	10,200	12,424	11,654	2,642	740	370	.....	.....
7	3,418	2,590	10,800	11,400	9,578	2,448	792	370	.....	.....
8	2,700	2,046	11,160	11,160	8,810	2,310	740	370	.....	.....
9	2,150	1,390	11,400	11,656	7,910	2,448	740	300	.....	.....
10	2,425	1,534	10,200	14,312	7,070	2,080	792	370	.....	.....
11	2,700	2,046	11,160	16,608	6,438	1,875	700	500	.....	.....
12	2,150	1,890	11,400	18,706	6,280	1,670	600	500	.....	.....
13	2,150	2,260	11,400	17,650	5,910	2,540	600	370	.....	.....
14	2,700	2,425	12,040	16,900	4,988	2,540	700	370	.....	.....
15	2,260	2,700	10,200	19,624	4,330	2,448	1,000	670	.....	.....

Mean daily discharge, in second-feet, of North Platte River at North Platte, etc.—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905.										
16	3,802	2,425	9,640	23,010	3,720	1,752	600	600		
17	4,770	2,425	8,040	20,326	3,160	1,670	370	470		
18	3,930	2,590	7,848	17,970	2,540	1,382	530	580		
19	4,770	2,425	7,848	16,690	2,948	1,490	800	620		
20	3,610	2,260	8,872	16,060	3,720	1,752	950	850		
21	2,700	4,620	8,040	14,200	4,200	1,155	700	850		
22	2,150	4,620	7,080	14,200	3,720	1,000	600	850		
23	1,734	4,068	6,635	14,446	2,948	870	700	700		
24	1,534	5,370	7,080	14,446	2,948	698	530	850		
25	1,534	7,272	8,872	12,098	3,050	698	470	1,060		
26	1,390	7,080	8,872	11,006	2,448	740	360	830		
27	1,390	6,190	15,732	10,586	2,540	698	320	830		
28	2,046	5,370	13,355	9,578	2,448	635	260	1,100		
29	2,150	6,635	15,158	9,002	3,490	530	330	1,270		
30	2,046	8,248	14,030	9,974	2,080	870	330	1,160		
31	2,150		13,355		2,448	792		1,100		
1906.										
1			7,490	15,400	6,910	1,900	2,080	1,200	2,400	
2			7,070	16,100	6,910	1,750	2,080	1,280	2,200	
3			7,490	16,400	7,070	1,320	1,940	1,220	3,340	
4			6,910	16,400	6,440	1,170	1,870	1,060	3,080	
5			7,240	19,000	6,280	1,230	1,870	1,060	2,570	
6			6,910	17,300	5,540	2,400	1,410	1,000	2,500	
7			5,540	16,200	4,850	3,320	1,120	920	2,370	
8			4,990	12,300	4,200	1,960	900	760	2,300	
9			4,850	9,770	4,080	1,380	840	980	2,300	
10		6,280	4,850	8,360	3,900	1,060	840	980	2,570	
11		6,130	4,990	8,090	3,900	1,000	1,280	980	2,660	
12		6,910	4,850	8,810	3,600	740	2,200	980	2,860	
13		7,910	5,200	8,810	3,720	570	1,770	950	2,350	
14		6,280	5,200	9,290	4,200	445	1,770	260	2,320	
15		5,910	5,910	8,810	3,900	530	1,340	1,260	2,080	
16		5,400	6,680	8,810	3,320	530	780	1,080	2,230	
17		5,540	6,130	7,240	2,640	394	1,160	1,200	2,080	
18		5,400	6,130	6,280	2,950	330	1,170	940	1,880	
19		6,440	7,240	7,070	3,160	260	1,170	1,020	1,880	
20		6,910	7,910	7,740	3,490	170	1,750	1,120	1,230	
21		6,280	9,580	9,000	3,720	100	1,750	760	750	
22		5,910	8,360	9,770	4,850	50	1,670	1,600	750	
23		5,540	8,360	9,580	4,330	1,140	1,560	3,000	1,100	
24		5,690	8,630	10,300	3,600	2,200	1,480	1,630	1,500	
25		5,400	11,000	9,970	3,720	1,340	1,550	1,260	2,230	
26		4,520	9,770	9,000	3,600	1,600	1,260	1,760	2,550	
27		5,910	9,770	9,290	3,900	1,040	1,200	2,480	2,080	
28		7,490	9,770	8,360	3,050	740	1,120	4,600	1,880	
29		6,440	9,970	7,490	2,540	740	1,060	5,300	1,880	
30		5,910	11,300	7,070	2,080	1,300	1,120	3,130	2,710	
31			13,200		2,080	2,300		2,520		

72607—IRR 230—09——7

Estimated monthly discharge of North Platte River at North Platte, 1895–1906.

[Drainage area, 28,500 square miles.]

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
March.								
1895	10,180	455	3,005	184,800	0.105	0.13	24	0.55
1897	9,490	1,770	3,921	241,100	.138	.16	9	1.76
1898	3,350	1,270	2,226	136,900	.078	.09	11	.79
1899	8,000	4,640	6,814	419,000	.239	.28	17	1.64
1900	6,900	1,320	3,082	189,500	.108	.12	43	.29
1901	9,900	1,320	3,260	200,400	.114	.13	13	1.00
1902[a]	4,050	950	2,257	71,600				1.12
1903[b]	14,300	2,520	6,562	221,200				.98
1904	2,070	1,000	1,370	84,200	.048	.05	7	.75
1905	4,990	1,390	2,727	167,800	.096	.11	14	.77
April.								
1895	6,540	1,550	3,470	206,500	.122	.13	19	.69
1896[c]	3,560	1,860	2,823	117,600				1.83
1897	13,490	2,470	5,110	304,100	.179	.20	14	1.41
1898	3,780	1,550	2,540	151,100	.089	.10	9	1.12
1899	9,850	3,020	6,509	387,300	.228	.26	33	.79
1900	6,900	1,800	4,108	244,000	.144	.16	4	4.34
1901	4,700	1,560	2,408	143,300	.084	.09	4	2.06
1902	3,440	1,320	2,443	145,400	.086	.10	8	1.26
1903	5,020	2,150	3,223	191,800	.113	.13	9	1.33
1904	3,360	1,030	1,938	115,300	.068	.08	8	.99
1905	8,250	1,390	3,743	222,700	.131	.15	4	3.45
1906	7,910	4,520	6,100	363,000	.214	.24	12	1.93
May.								
1895	10,630	4,880	7,033	432,400	.246	.29	17	1.71
1896	7,890	2,680	4,558	280,300	.160	.18	8	2.17
1897	21,530	7,810	13,981	859,700	.490	.56	41	1.37
1898	14,650	3,570	5,276	324,400	.185	.21	5	4.34
1899	13,370	4,640	9,196	565,400	.321	.37	12	3.18
1900	14,300	7,350	9,468	582,200	.331	.38	42	.91
1901	14,300	2,150	7,680	472,200	.269	.31	11	2.78
1902	9,900	3,440	5,450	335,100	.191	.22	9	2.47
1903	6,500	3,440	4,866	299,200	.171	.20	10	2.03
1904	11,370	3,770	5,644	347,000	.198	.23	8	2.87
1905	15,730	6,630	10,270	631,500	.360	.42	12	3.43
1906	13,200	4,850	7,530	463,000	.264	.30	12	2.63
June.								
1895	16,870	6,190	10,991	654,000	.385	.44	13	3.36
1896	16,300	2,680	6,334	376,900	.222	.24	9	2.65
1897	23,720	6,520	13,920	828,300	.488	.54	43	1.26
1898	12,030	4,430	6,878	409,300	.241	.27	15	1.75
1899	18,300	10,960	13,845	823,800	.486	.55	33	1.67
1900	17,700	4,700	10,858	548,100	.380	.42	52	.81
1901	17,700	4,050	9,733	579,100	.342	.38	14	2.66
1902	6,900	2,950	5,139	305,800	.180	.20	7	2.70
1903	12,700	2,730	6,825	406,100	.239	.27	16	1.71
1904	15,480	6,670	10,260	610,500	.360	.40	14	2.97
1905	23,010	9,000	14,700	874,700	.515	.58	27	2.11
1906	19,000	6,280	10,600	631,000	.372	.42	25	1.71
July.								
1895	5,850	842	3,137	192,900	.110	.13	10	1.26
1896	2,680	250	1,134	69,700	.040	.05	2	1.88
1897	6,200	1,090	3,688	226,800	.129	.15	10	1.55
1898	4,430	324	1,846	113,500	.065	.08	5	1.68
1899	16,260	4,920	10,743	660,600	.377	.44	28	1.55
1900	5,350	1,120	2,255	138,600	.079	.09	4	2.39
1901	4,050	75	1,508	92,700	.053	.06	8	.75
1902	6,100	370	2,229	137,000	.078	.09	5	1.75
1903	8,300	670	3,348	205,800	.117	.13	6	2.11
1904	7,260	800	3,681	226,300	.129	.15	8	1.86
1905	15,180	2,080	5,983	367,900	.210	.24	9	2.67
1906	7,070	2,070	4,150	255,000	.146	.17	14	1.25
August.								
1895	963	231	492	30,200	.017	.02	3	.77
1896	1,860	460	919	56,500	.032	.04	3	1.12
1897	4,750	743	2,876	176,800	.101	.12	6	1.96
1898	1,140	80	353	21,700	.012	.01	1	.83

[a] March 16 to 31. [b] March 15 to 31. [c] April 10 to 30.

Estimated monthly discharge of North Platte River at North Platte, 1895–1906—Cont'd.

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
August.								
1899	8,560	1,320	3,866	237,800	0.135	0.16	13	1.23
1900	2,150	100	581	35,700	.020	.02	3	.58
1901	800	50	346	21,300	.012	.01	1	1.17
1902	370	30	102	6,300	.004	.005	0.5	.99
1903	1,220	370	711	43,700	.025	.03	2	1.79
1904	2,070	32	399	24,500	.014	.02	2	.92
1905	4,330	530	1,862	114,500	.065	.08	6	1.25
1906	3,320	50	1,130	69,500	.040	.05	2	2.04
September.								
1895	455	150	241	14,300	.008	.01	4	.25
1896	1,130	550	857	51,000	.030	.03	6	.57
1897	850	422	609	36,200	.021	.02	5	.47
1898	984	70	352	20,900	.012	.01	1	.78
1899	2,210	850	1,148	68,300	.040	.04	8	.51
1900	325	70	111	6,600	.004	.004	0.3	1.19
1901	1,800	565	1,068	63,500	.037	.04	0.4	1.09
1902	1,800	100	481	28,600	.017	.02	9	2.10
1903	800	325	545	32,400	.019	.02	1	1.56
1904	910	20	159	9,500	.006	.01	0.5	1.09
1905	1,000	260	585	34,800	.021	.02	2	1.32
1906	2,200	780	1,470	87,500	.052	.06	3	1.98
October.								
1895	1,390	200	810	49,800	.028	.02	9	.23
1896	2,510	730	1,150	70,700	.040	.05	7	.70
1897	3,880	486	1,132	69,600	.040	.05	4	1.07
1898	697	254	471	29,000	.016	.02	3	.63
1899	1,560	413	964	59,300	.034	.04	3	1.22
1900	875	370	533	32,800	.019	.02	4	.54
1901	1,320	670	1,121	68,900	.039	.05	6	.87
1902	1,120	670	1,035	63,600	.036	.04	5	.90
1903	1,220	875	1,087	66,800	.038	.04	9	.51
1904	1,790	538	1,167	71,800	.041	.05	5	.99
1905	1,270	200	616	37,900	.022	.02	2	.82
1906	5,300	760	1,590	97,800	.056	.06	3	2.07
November.								
1895	1,900	963	1,357	80,700	.047	.06	9	.65
1896	3,720	730	2,166	128,900	.075	.08	18	.45
1897	4,110	743	2,152	128,000	.075	.08	14	.60
1898	2,270	660	1,088	64,700	.038	.04	5	.74
1899	2,280	1,270	1,813	107,900	.063	.07	16	.45
1900	2,150	670	1,114	66,500	.039	.04	20	.20
1901	1,800	1,320	1,576	93,800	.055	.07	28	.25
1902	1,560	800	1,104	65,700	.039	.04	28	.14
1903[a]	1,440	565	1,316	17,000				.26
1904	1,900	1,150	1,517	80,300	.053	.06	300	.02
1906	3,340	750	2,150	128,300	.075	.08	9	.87

[a] November 1 to 18.

SOUTH PLATTE DRAINAGE BASIN.

DESCRIPTION OF BASIN.

The headwaters of the South Platte have their sources in the mountainous region surrounding the large basin near the center of Colorado known as South Park, and in the long eastern slopes of the high mountains forming the Continental Divide. The general course of the stream is eastward to Lake George, thence through Platte Canyon northward to the junction with Cache la Poudre River near Greeley, Colo., and thence eastward until it joins the North Platte at the town of North Platte, Nebr.

The drainage basin, which is about 20,000 square miles in extent above Julesburg, Colo., is bisected in an irregular way by the channel of the South Platte. To the north and west lies the mountainous portion, which consists of a long, narrow strip lying in a north-south direction along the foothills from a point a short distance within Wyoming to Palmer Lake, Colo. This area produces at least 90 per cent of the total run-off of the basin. South and east of the river the basin lies entirely within the plains region.

The mountainous region consists of peaks and jagged masses of granite, with sedimentary rocks cut and gashed by stream channels along the foothills. The stream gradients are steep, and many of the streams consist of series of cascades and rapids. The soil cover as a whole is light, and except during spring freshets or heavy storms the streams are remarkably free from sediments in suspension. The forest cover of the mountains, consisting originally of coniferous trees, is rapidly disappearing, but through the occurrence of fires a foothold has been furnished for the deciduous aspen, which is gradually increasing its dominion. The South Platte, Plum Creek, and Medicine Bow national forests are in part comprised within this area.

The lower basin, somewhat broken and scarred along the foothills, gradually merges farther east into the undulating prairies so characteristic of the Great Plains east of the Rocky Mountains. The soils of the plains are the product of the disintegration of shales and sandstones and range from adobe clays to sandy loams. The controlling vegetation consists largely of native grasses, the only timber being a few bunches of scraggly cottonwoods along the stream channels and small patches of pine, cedar, and piñon along the higher portions.

Precipitation varies from 25 inches along the Continental Divide, where the greater part of it is snowfall, to 14 to 17 inches among the foothills. Evaporation records are meager.

In the mountainous region the flow of the South Platte and its tributaries is perennial; but in the plains area the volume is greatly diminished, owing to the fact that the normal waters are completely diverted for irrigation, the acreage capacity of the canals far exceeding the capacity of the river. At North Platte, Nebr., just above the mouth of the river, the stream channel is dry for the greater part of the year or consists of several small channels carrying a few second-feet of water.

The tributaries of the South Platte comprise, first, the small streams that rise on the eastern slopes of the Rocky Mountains, and, second, the plains streams. The mountain streams furnish a perennial supply of water, the amount of which, however, varies with the snowfall, being light during the latter part of the summer and in the fall and winter, and large during the spring floods. This water is almost entirely diverted for irrigation and does not reach the South Platte

except in times of heavy floods. The principal streams of this class are Bear, Clear, Boulder, St. Vrain, and Thompson creeks and Cache la Poudre River. The plains streams are all intermittent in their nature and furnish water only during storms or in the season of melting snow. The chief streams of this class are Cherry, Lone Tree, Kiowa, Boxelder, Bijou, Beaver, and Pawnee creeks.

The South Platte is subject to periodic floods, which occur in May and June, the magnitude varying from year to year with seasonal precipitation and temperature.

SOUTH PLATTE RIVER AT JULESBURG, COLO.

The station at Julesburg, Colo., was established April 2, 1902, and has been maintained continuously since that date. It is located at the highway bridge 1 mile southeast of Julesburg, in sec. 28, T. 12 N., R. 43 W., near the Nebraska-Colorado state line. One irrigation canal heads between the gaging station and the state line. In Nebraska, however, there are a number of important ditches.

The bed is composed of loose, shifting sand and is dotted with islands covered with undergrowth and other vegetation. The banks are low but seldom overflow. The channel is about 2,000 feet wide between banks.

The gage is a vertical staff spiked to a piling on the downstream side of the bridge 1,600 feet from the north end. The bench mark is a spike in the south face of the piling directly over the gage, marked "B. M."; elevation, 8.00 feet above the zero of the gage.

Discharge measurements of South Platte River at Julesburg, Colo., 1902–1906.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Sec.-ft.*	1904.		*Feet.*	*Sec.-ft.*
April 2	J. E. Field	1.30	35	April 16	T. W. Jenkins	1.10	12
October 10	S. G. Lees	1.58	133	April 30	do	1.42	65
November 8	R. W. Hawley	1.15	31	May 9	do	2.02	546
				May 27	do	1.76	228
1903.				June 3	do	2.60	1,542
April 1	J. C. Stevens	2.35	1,145	June 7	do	2.98	2,988
May 9	do	1.00	25				
September 22	E. C. Murphy	1.00	4	1905.			
April 17	M. C. Hinderlider	1.22	40	May 6	do	3.75	5,643
May 11	R. I. Meeker	1.09	36	May 10	M. C. Hinderlider	3.50	5,216
Do	do		42	May 20	T. W. Jenkins	3.27	4,130
July 23	M. C. Hinderlider	.95	1	May 25	do	3.48	4,748
June 13	do	1.00	11	May 27	do	3.99	7,405
December 23	do	2.68	526	October 4	M. C. Hinderlider	1.05	37
1904.				1906.			
March 8	do	1.35	88	February 24	do	1.90	918
March 16	T. W. Jenkins	1.18	19	March 30	do	2.20	1,200
March 26	do	1.18	23	June 23	do	1.48	71
April 2	do	1.17	15	November 6	R. I. Meeker	2.78	1,940
April 9	do	1.18	16				

Mean daily gage height, in feet, of South Platte River at Julesburg, Colo., 1902–1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1				1.30	1.20	1.20	1.10	0.75	0.75	2.30	1.15	1.40
2				1.30	1.25	1.10	1.10	.75	.75	2.20	1.15	1.40
3				1.30	1.25	1.05	1.50	.75	.75	2.00	1.15	1.40
4				1.30	1.25	1.05	1.25	.80	.75	1.80	1.15	1.55
5				1.25	1.20	1.05	1.15	.80	.75	1.75	1.15	1.75
6				1.25	1.20	1.15	1.15	.80	.75	1.70	1.15	1.90
7				1.25	1.20	1.15	1.15	.75	.75	1.70	1.15	2.00
8				1.20	1.15	1.15	1.00	.75	.75	1.70	1.15	2.20
9				1.20	1.15	1.00	1.00	.75	.75	1.65	1.15	2.45
10				1.20	1.15	1.00	1.00	.75	.75	1.55	1.15	2.50
11				1.20	1.15	1.00	.90	.75	.75	1.50	1.15	2.50
12				1.20	1.30	1.60	.90	.75	.75	1.45	1.15	2.50
13				1.20	1.20	1.35	.90	.75	.75	1.40	1.15	2.60
14				1.45	1.20	1.25	.80	.75	.75	1.40	1.20	2.60
15				1.40	1.30	1.25	.80	.75	.75	1.35	1.20	2.60
16				1.30	1.25	1.20	.80	.75	.75	1.30	1.20	2.60
17				1.30	1.20	1.20	.80	.75	.75	1.25	1.20	2.60
18				1.25	1.15	1.10	.80	.70	.75	1.20	1.20	2.60
19				1.20	1.20	1.10	.80	.70	.75	1.20	1.20	2.70
20				1.20	1.30	1.10	.80	.70	.75	1.20	1.20	.....
21				1.25	1.20	1.10	.80	.80	1.20	1.20	1.20	2.75
22				1.30	1.15	1.00	.80	.80	1.90	1.25	1.20	2.80
23				1.40	1.15	1.00	.80	.80	1.90	1.25	1.20	2.80
24				1.30	1.10	.95	.80	.80	2.00	1.25	1.20	2.85
25				1.30	1.10	.95	.85	.80	2.00	1.20	1.20	2.90
26				1.25	1.25	.90	.85	.80	2.10	1.20	1.25	.....
27				1.20	1.25	1.00	1.75	.80	2.20	1.20	1.30	.....
28				1.20	1.25	1.10	1.00	.80	2.30	1.20	1.40	.....
29				1.20	1.20	1.10	.80	.75	2.30	1.20	1.40	.....
30				1.20	1.25	1.10	.80	.75	2.30	1.15	1.40	.....
31				.....	1.25	.....	.75	.75	.....	1.15	.....	.....
1903.												
1				2.30	1.00	1.00	1.00	.90	1.00	1.05	.....	1.70
2				2.30	1.00	1.05	.95	.90	1.00	1.05	.....	1.60
3				2.30	1.00	1.05	.95	.90	1.00	1.05	.....	1.55
4				2.30	1.00	1.05	.95	.90	1.00	1.05	.....	1.50
5				2.25	1.00	1.05	.95	.90	1.00	1.05	.....	1.45
6				2.15	1.00	1.05	.95	.90	1.00	1.05	.....	1.75
7				2.50	1.10	1.05	.95	.90	1.00	1.05	.....	1.80
8				2.00	.....	1.05	.95	.95	1.00	1.05	.....	1.90
9				2.00	.....	1.05	.95	.95	1.00	1.05	.....	1.10
10				1.95	1.00	1.10	.95	.95	1.00	1.05	1.05	2.00
11				1.85	1.50	1.05	.95	.95	1.00	1.05	1.05	2.10
12				1.80	1.00	1.05	.95	.95	1.00	1.05	1.05	2.15
13				1.50	1.00	1.00	.95	.95	1.00	1.05	1.05	2.15
14				1.50	1.00	1.00	.95	.95	1.00	1.05	1.05	2.15
15			3.30	1.30	1.00	1.00	.95	.95	1.00	1.05	1.05	2.20
16				1.20	1.00	1.00	.95	2.28	1.00	1.05	1.10	2.40
17				1.15	1.15	1.00	.95	1.73	1.05	1.05	1.10	2.40
18			2.65	1.15	1.10	1.00	.95	1.20	1.05	1.00	1.10	2.40
19			2.60	1.25	1.00	1.00	.95	1.10	1.05	1.00	1.10	2.45
20			2.55	1.30	1.00	1.00	.95	1.10	1.05	1.00	1.10	2.70
21			2.50	1.20	1.00	1.00	.95	1.05	1.05	1.00	1.10	2.70
22			2.50	1.10	1.00	1.00	.95	1.05	1.05	1.00	1.10	2.90
23			2.50	1.10	1.00	1.00	.95	2.20	1.05	1.00	1.10	2.70
24			2.65	1.00	1.00	1.00	.95	1.95	1.05	1.00	1.10	2.65
25			2.40	1.00	1.00	1.00	.90	1.35	1.05	1.00	1.60	2.60
26			2.40	.95	1.00	1.00	.90	1.10	1.05	1.00	1.90	2.50
27			2.30	.95	1.00	1.00	.90	1.05	1.05	1.00	1.85	2.40
28			2.30	.95	1.00	1.00	.90	1.05	1.05	1.00	1.85	2.40
29			2.30	1.00	1.10	1.00	.90	1.05	1.05	1.00	1.85	2.40
30			2.30	1.50	1.50	1.00	.90	1.00	1.05	1.00	1.75	2.40
31			2.30	.....	1.00	.....	.90	1.00	.....	1.00	.....	2.40
1904.												
1			1.90	1.15	1.40	2.00	2.10	1.30	1.30	1.60	1.40	1.65
2			1.75	1.15	1.30	2.61	1.85	1.30	1.30	1.60	1.35	1.65
3			1.65	1.15	1.30	2.50	1.85	2.15	1.25	1.55	1.35	1.60
4			1.55	1.15	1.30	2.20	1.75	1.40	1.25	1.50	1.30	1.60
5			1.60	1.20	1.40	2.00	1.65	1.35	1.20	1.50	1.30	1.75

Mean daily gage height, in feet, of South Platte River at Julesburg, Colo,, etc.—Cont'd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.												
6			1.60	1.20	1.40	3.15	1.60	1.35	1.20	1.45	1.30	1.80
7			1.45	1.20	1.35	3.00	1.85	1.35	1.20	1.45	1.30	1.75
8			1.35	1.20	1.35	3.20	1.80	1.30	1.20	1.65	1.30	1.85
9			1.35	1.20	2.00	3.00	1.70	1.30	1.20	1.60	1.30	1.85
10			1.30	1.20	1.80	2.90	1.60	1.30	1.20	1.55	1.30	1.85
11			1.25	1.20	1.70	2.65	1.60	1.25	1.20	1.55	1.30	1.85
12			1.20	1.15	1.60	2.55	1.95	1.25	1.20	1.50	1.30	1.85
13			1.20	1.15	1.45	2.50	1.90	1.25	1.20	1.40	1.30	1.85
14			1.20	1.15	1.40	2.75	1.80	1.25	1.20	1.40	1.35	1.90
15			1.20	1.00	1.35	2.80	1.60	1.25	1.15	1.35	1.40	1.90
16			1.20	1.00	1.35	2.70	1.55	1.20	1.15	1.30	1.65	.....
17			1.20	1.00	1.30	2.70	1.50	1.20	1.15	1.30	1.60	.....
18			1.20	1.00	1.30	2.70	1.45	1.35	1.15	1.40	1.55	.....
19			1.20	1.00	1.30	2.70	1.45	1.30	1.15	1.45	1.55	.....
20			1.20	1.15	1.30	2.65	1.60	1.25	1.15	1.40	1.55	.....
21			1.20	1.20	1.30	2.60	1.60	1.25	1.15	1.35	1.55	.....
22			1.20	1.20	1.30	2.55	1.60	1.25	1.15	1.30	1.60	.....
23			1.20	1.20	1.30	2.50	1.60	1.20	1.15	1.30	1.60	.....
24			1.20	1.20	1.30	2.45	1.60	1.20	1.15	1.30	1.65	.....
25			1.20	1.25	1.30	2.40	1.60	1.20	1.15	1.30	1.80	.....
26			1.20	1.20	1.30	2.40	1.55	1.20	1.15	1.30	1.80	.....
27			1.20	1.15	1.75	2.35	1.50	1.20	1.15	1.30	1.80	.....
28			1.20	1.00	1.60	2.30	1.50	1.20	1.15	1.35	1.75	.....
29			1.20	1.20	1.60	2.25	1.45	1.20	1.15	1.55	1.75	.....
30			1.15	1.45	1.65	2.20	1.35	1.20	1.65	1.50	1.70	.....
31			1.15	.....	1.80	.....	1.30	1.20	.....	1.45	.....	.....
1905.												
1	2.55	.....	2.0	1.95	3.65	4.35	.75	1.63	1.2	1.05	1.5	1.65
2	2.6	.....	2.0	2.5	3.75	4.35	1.5	1.85	1.15	1.05	1.65	1.65
3	2.6	.....	2.0	1.95	3.85	4.0	1.4	2.05	1.15	1.05	1.85	1.65
4	2.6	.....	2.0	1.9	3.85	3.85	1.2	3.0	1.1	1.05	1.9	1.65
5	2.6	.....	2.0	1.95	3.8	3.8	.7	2.8	1.15	1.05	2.0	1.9
6	2.7	.....	2.15	1.95	3.75	3.85	.6	2.9	1.2	1.05	2.0	1.9
7	2.8	.....	2.05	2.5	3.7	3.9	.55	2.75	1.2	1.05	2.0	1.9
8	2.8	.....	2.1	2.5	3.75	4.0	.5	2.3	1.35	1.05	2.25	1.95
9	2.75	.....	2.15	2.5	3.75	4.5	.5	2.2	1.15	1.05	2.0	2.0
10	2.7	.....	2.0	2.1	3.6	4.0	.45	2.15	1.15	1.05	1.9	2.1
11	.....	.....	2.0	2.15	3.45	4.95	.4	2.5	1.1	1.05	1.9	2.1
12	.....	.....	2.5	2.25	3.35	4.95	.4	2.45	1.1	1.15	1.9	2.1
13	2.65	.....	1.95	2.25	3.45	4.0	2.0	2.35	1.1	1.25	2.0	2.1
14	2.65	.....	2.0	2.25	3.5	3.95	1.9	2.3	1.1	1.2	2.0	2.15
15	2.65	.....	2.5	2.5	3.5	3.55	1.8	2.0	1.1	1.25	1.9	2.2
16	2.65	.....	2.1	2.4	3.45	3.5	1.75	2.1	1.15	1.35	1.8	2.2
17	2.7	.....	2.5	2.5	3.35	3.3	1.9	2.15	1.2	1.25	1.75	2.1
18	2.8	.....	2.5	2.55	3.35	3.1	1.8	2.2	1.15	1.3	1.65	2.15
19	2.95	.....	2.2	2.4	3.4	3.0	1.85	2.25	1.15	1.35	1.7	2.2
20	3.15	.....	2.1	2.75	3.3	3.0	1.75	1.75	1.1	1.32	1.6	2.15
21	3.25	.....	2.0	2.7	3.45	2.85	1.7	1.65	1.1	1.35	1.65	2.25
22	.....	.....	1.9	2.65	3.45	2.4	2.0	1.6	1.1	1.4	1.6	2.2
23	.....	.....	1.95	2.7	3.45	1.0	1.95	1.45	1.1	1.4	1.75	2.2
24	.....	.....	1.95	3.5	3.5	.85	1.9	1.3	1.05	1.35	1.65	2.15
25	.....	.....	1.9	3.2	3.5	.95	1.85	1.2	1.05	1.5	1.65	2.0
26	.....	.....	1.9	3.1	4.0	1.0	1.7	1.15	1.05	1.5	1.65	2.1
27	.....	.....	1.9	3.5	4.0	.95	1.65	1.1	1.05	1.45	1.65	2.1
28	.....	.....	1.9	3.4	4.2	.95	1.6	1.1	1.05	1.5	1.65	2.2
29	.....	.....	1.9	3.6	4.3	.95	1.65	1.1	1.0	1.5	1.65	2.2
30	.....	.....	1.8	3.6	4.3	.9	1.75	1.12	1.15	1.5	1.65	2.2
31	.....	.....	1.95	.....	4.35	.....	1.7	1.12	.....	1.5	.....	2.25
1906.												
1	.....	1.9	.....	2.2	1.6	1.5	1.4	.....	.....	.....	2.6	.....
2	.....	1.9	.....	2.25	1.6	1.4	.....	1.2	1.3	1.45	.....	.....
3	.....	1.9	1.9	2.2	1.6	1.45	1.4	.....	.....	.....	.....	.....
4	.....	1.85	1.9	1.95	1.6	1.45	.....	1.2	1.3	1.35	2.6	.....
5	.....	1.85	1.9	2.0	1.7	1.4	1.4	.....	.....	.....	.....	.....
6	.....	.....	1.9	1.95	1.75	1.4	.....	1.2	1.1	1.45	2.6	.....
7	.....	.....	2.2	1.95	2.0	1.35	1.35	1.45	.....	.....	.....	.....
8	.....	1.9	2.75	1.85	2.2	1.35	.....	.....	1.15	1.95	2.6	.....
9	.....	1.9	2.85	1.9	2.05	1.3	1.3	1.45	.....	.....	.....	.....
10	.....	1.9	.....	1.9	2.05	1.35	.....	.....	1.15	1.95	2.6	.....

Mean daily gage height, in feet, of South Platte River at Julesburg, Colo., etc.—Cont'd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906.												
11		1.9	2.7	1.9	2.05	1.3	1.4	1.25			2.5	
12		2.2		1.9	2.05	1.4			1.4	1.95	2.75	
13		2.75		2.5	2.0	1.35	1.35	1.25				
14				1.95	1.9	1.5			1.35	1.95	2.75	
15				1.9	1.8	1.3	1.45	1.3				
16				1.8	1.75	1.3			1.35	1.95	2.75	
17				1.9	1.6	1.3	1.35	1.3				
18				1.9	1.55	1.3			1.35	1.85		
19				1.95	1.5	1.3	1.35	1.2	1.35			
20				1.9	1.4	1.25			1.35	1.95		
21				1.85	1.35	1.2	1.35	1.15				
22				1.8	1.35	1.3			1.35	1.95		
23				1.8	1.5	1.45	1.3	1.15				
24		1.9		1.8	1.55	1.4			1.4	2.5		
25		1.9		1.8	1.7	1.4	1.3	1.15				
26		1.9		1.8	1.9	1.4			1.35	2.8		
27		1.85	2.25	1.8	1.9	1.4	1.35	1.15				
28		1.85	2.45	1.6	1.85	1.4			1.35	2.8		
29			2.25	1.6	1.7	1.4	1.3	1.15				
30			2.25	1.6	1.6	1.4			1.35	2.8		
31			2.25		1.55		1.3	1.2				

Mean daily discharge, in second-feet, of South Platte River at Julesburg, Colo., 1902–1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1				52	35	35	23	2	2	662	28	75
2				52	43	23	23	2	2	573	28	75
3				52	43	19	105	2	2	407	28	75
4				52	43	19	43	4	2	258	28	123
5				43	35	19	28	4	2	225	28	225
6				43	35	28	28	4	2	195	28	330
7				43	35	23	28	2	2	195	28	407
8				35	28	28	15	2	2	195	28	573
9				35	28	15	15	2	2	168	28	803
10				35	28	15	15	2	2	123	28	852
11				35	28	15	9	2	2	105	28	852
12				35	52	144	9	2	2	89	28	852
13				35	35	63	9	2	2	75	28	953
14				89	35	43	4	2	2	75	35	953
15				75	52	43	4	2	2	63	35	953
16				52	43	35	4	2	2	52	35	953
17				52	35	35	4	2	2	43	35	953
18				43	28	23	4	0	2	35	35	953
19				35	35	23	4	0	2	35	35	1,058
20				35	52	23	4	0	2	35	35	1,085
21				43	35	23	4	4	35	35	35	1,112
22				52	28	15	4	4	330	43	35	1,167
23				75	28	15	4	4	330	43	35	1,167
24				52	23	12	4	4	407	43	35	1,223
25				52	23	12	6	4	407	35	35	1,280
26				43	43	9	6	4	488	35	43	
27				35	43	15	225	4	573	35	52	
28				35	43	23	15	4	662	35	75	
29				35	35	23	4	2	662	35	75	
30				35	43	23	4	2	662	28	75	
31					43		2	2		28		
1903												
1				1,089	9	9	9	1	9	22	[a] 9	
2				1,089	9	22	3	1	9	22	9	
3				1,089	9	22	3	1	9	22	9	
4				1,089	9	22	3	1	9	22	9	
5				1,043	9	22	3	1	9	22	22	

[a] November 1–9 estimated.

Mean daily discharge, in second-feet, of South Platte River at Julesburg, Colo., etc.—Con.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1903.												
6				952	9	22	3	1	9	22	22	
7				1,271	42	22	3	1	9	22	22	
8				816	[a] 22	22	3	3	9	22	22	
9				816	[a] 22	22	3	3	9	22	22	
10				770	9	42	3	3	9	22	22	
11				679	361	22	3	3	9	22	22	
12				634	9	22	3	3	9	22	22	
13				361	9	9	3	3	9	22	22	
14				361	9	9	3	3	9	22	22	
15			[b]	180	9	9	3	3	9	22	22	
16				96	9	9	3	[c] 1,071	9	22	42	
17				66	66	9	3	570	22	22	42	
18				66	42	9	3	96	22	9	42	
19				138	9	9	3	42	22	9	42	
20				180	9	9	3	42	22	9	42	
21				96	9	9	3	22	22	9	42	
22				42	9	9	3	22	22	9	42	
23				42	9	9	3	998	22	9	42	
24				9	9	9	3	770	22	9	42	
25				9	9	9	1	225	22	9	[d]	
26				3	9	9	1	42	22	9		
27				3	9	9	1	22	22	9		
28				3	9	9	1	22	22	9		
29				9	42	9	1	22	22	9		
30				361	361	9	1	9	22	9		
31					9		1	9		9		
1904.												
1			360	15	60	465	590	35	35	140	60	165
2			230	15	35	1,576	315	35	35	140	45	165
3			165	15	35	1,315	315	660	25	115	45	140
4			115	15	35	735	230	60	25	95	35	140
5			140	20	60	465	165	45	20	95	35	230
6			140	20	60	3,780	140	45	20	75	35	270
7			75	20	45	3,060	315	45	20	75	35	230
8			45	20	45	4,040	270	35	20	165	35	315
9			45	20	465	3,060	195	35	20	140	35	315
10			35	20	270	2,620	140	35	20	115	35	315
11			25	20	195	1,680	140	25	20	115	35	315
12			20	15	140	1,430	410	25	20	95	35	315
13			20	15	75	1,315	360	25	20	60	35	315
14			20	15	60	2,000	270	25	20	60	45	360
15			20	4	45	2,200	140	25	15	45	60	360
16			20	4	45	1,830	115	20	15	35	165	
17			20	4	35	1,830	95	20	15	35	140	
18			20	4	35	1,830	75	45	15	60	115	
19			20	4	35	1,830	75	35	15	75	115	
20			20	15	35	1,680	140	25	15	60	115	
21			20	20	35	1,550	140	25	15	45	115	
22			20	20	35	1,430	140	25	15	35	140	
23			20	20	35	1,315	140	20	15	35	140	
24			20	20	35	1,205	140	20	15	35	165	
25			20	25	35	1,100	140	20	15	35	270	
26			20	20	35	1,100	115	20	15	35	270	
27			20	15	230	1,000	95	20	15	35	270	
28			20	4	140	905	95	20	15	45	230	
29			20	20	140	815	75	20	15	115	230	
30			15	75	165	735	45	20	165	95	195	
31			15		270		35	20		75		
1905.												
1	1,425		[e] 470	422	5,745	9,230	17	192	50	34	131	202
2	1,550		470	1,300	6,220	9,230	131	335	44	34	202	202
3	1,550		470	442	6,705	7,450	98	530	44	34	335	202
4	1,550		470	375	6,705	6,705	50	2,870	37	34	375	202
5	1,550		470	422	6,460	6,460	15	2,140	44	34	470	375

[a] Observer absent; gage height assumed.
[b] Ice, March 15–31.
[c] Heavy rain.
[d] Ice, November 25 to December 31.
[e] March 1–4, gage height estimated.

Mean daily discharge, in second-feet, of South Platte River at Julesburg, Colo., etc.—Con.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905.												
6	1,830	.....	660	422	6,220	6,705	12	2,490	50	34	470	375
7	2,140	.....	530	1,300	5,980	6,950	11	1,985	50	34	470	375
8	2,140	.....	590	1,300	6,220	7,450	10	890	84	34	810	422
9	1,985	.....	660	1,300	6,220	10,010	10	730	44	34	470	470
10	1,830	.....	470	590	5,510	7,450	9	660	44	34	375	590
11	.....	.....	470	660	4,810	12,385	9	1,300	37	34	375	590
12	.....	.....	1,300	810	4,355	12,385	9	1,190	37	44	375	590
13	1,690	.....	422	810	4,810	7,450	470	985	37	60	470	590
14	1,690	.....	470	810	5,040	7,200	375	890	37	50	470	660
15	1,690	.....	1,300	1,300	5,040	5,275	295	470	37	60	375	730
16	1,690	.....	590	1,080	4,810	5,040	262	590	44	84	295	730
17	1,830	.....	1,300	1,300	4,355	4,130	375	660	50	60	262	590
18	2,410	.....	1,300	1,425	4,355	3,270	295	730	44	70	202	660
19	2,680	.....	730	1,080	4,580	2,870	335	810	44	84	230	730
20	3,480	.....	590	1,985	4,130	2,870	262	262	37	76	175	660
21	3,910	.....	470	1,830	4,810	2,315	230	202	37	84	202	810
22	.....	.....	375	1,690	4,810	1,080	470	175	37	98	175	730
23	.....	.....	422	1,830	4,810	30	422	114	37	98	162	730
24	.....	.....	422	5,040	5,040	22	375	70	34	84	202	660
25	.....	.....	375	3,690	5,040	27	335	50	34	84	202	470
26	.....	.....	375	3,270	7,450	30	230	44	34	84	202	590
27	.....	.....	375	5,040	7,450	27	202	37	34	114	202	590
28	.....	.....	375	4,580	8,460	27	175	37	34	131	202	730
29	.....	.....	375	5,510	8,970	27	202	37	34	131	202	730
30	.....	.....	295	5,510	8,970	24	262	40	44	131	202	730
31	.....	.....	442	.....	9,230	.....	230	40	.....	131	.....	810
1906.[a]												
1	.....	920	.....	1,200	210	77	48	21	21	50	1,430	.....
2	.....	920	.....	1,300	210	48	48	14	28	62	1,430	.....
3	.....	920	920	1,200	210	62	48	14	28	50	1,430	.....
4	.....	870	920	700	210	62	48	14	28	28	1,430	.....
5	.....	870	920	780	250	48	48	14	18	50	1,430	.....
6	.....	870	920	700	290	48	43	14	7	62	1,430	.....
7	.....	920	1,350	700	570	38	38	62	8	211	1,430	.....
8	.....	920	2,800	560	880	38	33	62	10	360	1,430	
9	.....	920	3,120	630	640	28	28	62	10	360	1,430	.....
10	.....	920	.....	630	640	38	38	42	10	360	1,430	.....
11	.....	920	2,650	630	640	28	48	21	29	360	1,200	.....
12	.....	1,350	.....	580	640	48	43	21	48	360	1,850	.....
13	.....	2,800	.....	1,800	530	38	38	21	43	360	1,850	.....
14	.....	.....	.....	650	410	77	50	24	38	360	1,850	.....
15	.....	.....	.....	580	310	28	62	28	38	360	1,850	.....
16	.....	.....	.....	460	260	28	50	28	38	360	1,850	.....
17	.....	.....	.....	580	170	28	38	28	38	315	.....	.....
18	.....	.....	.....	580	140	28	38	21	38	270	.....	.....
19	.....	.....	.....	650	115	28	38	14	38	315	.....	.....
20	.....	.....	.....	540	75	21	38	12	38	360	.....	.....
21	.....	.....	.....	480	50	14	38	10	38	360	.....	.....
22	.....	.....	.....	420	50	28	33	10	38	360	.....	.....
23	.....	.....	.....	420	100	62	28	10	43	780	.....	.....
24	.....	920	.....	420	120	48	28	10	48	1,200	.....	.....
25	.....	920	.....	420	200	48	28	10	43	1,600	.....	.....
26	.....	920	.....	420	370	48	33	10	38	2,000	.....	.....
27	.....	870	1,300	420	370	48	38	10	38	2,000	.....	.....
28	.....	870	1,730	210	320	48	33	10	38	2,000	.....	.....
29	.....	.....	1,300	210	165	48	28	10	38	2,000	.....	.....
30	.....	.....	1,300	210	115	48	28	12	38	2,000	.....	.....
31	.....	.....	1,300	.....	95	.....	28	14	.....	1,720	.....	.....

[a] Approximate.

Estimated monthly discharge of South Platte River at Julesburg, Colo., 1902–1906.

[Drainage area, 20,600 square miles.]

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum	Mean.		Second-feet per square mile.	Depth in inches.
January.						
1905 [a]	3,910	1,420	2.018	76,000	.....	.....
February.						
1906 [b]	2,800	870	1,030	36,800	0.050	0.03
March.						
1904	360	15	57	3,500	.003	.003
1905	1,300	295	581	35,700	.028	.03
1906 [c]	3,120	920	1,580	40,700	.077	.04
April.						
1902	89	35	46	2,700	.002	.002
1903	1,270	3	445	26,500	.022	.02
1904	75	4	17.3	1,000	.001	.001
1905	5,510	375	1,903	113,200	.092	.10
1906	1,800	210	636	37,800	.031	.03
May.						
1902	52	23	37	2,300	.002	.002
1903	361	9	38	2,300	.002	.002
1904	465	35	96	5,900	.005	.005
1905	9,230	4,130	5,913	363,600	.287	.33
1906	880	50	302	18,600	.015	.02
June.						
1902	144	9	28	1,700	.001	.002
1903	42	9	14	833	.001	.001
1904	4,040	465	1,663	99,000	.081	.09
1905	12,380	24	4,804	285,800	.233	.26
1906	77	15	42.6	2,530	.0021	.002
July.						
1902	225	2	19	1,200	.001	.001
1903	9	1	3	184	.0001	.0002
1904	590	35	182	11,200	.009	.01
1905	470	9	199	12,200	.010	.01
1906	62	28	38.9	2,390	.0019	.002
August.						
1902	4	0	3	184	.0001	.0001
1903	1,070	1	130	8,000	.006	.007
1904	660	20	49	3,000	.002	.003
1905	2,870	37	695	42,700	.034	.04
1906	62	10	21.1	1,300	.0010	.001
September.						
1902	662	2	153	9,100	.007	.008
1903	22	9	15	893	.001	.001
1904	165	15	23.7	1,400	.001	.001
1905	84	34	41.8	2,500	.002	.002
1906	48	7	30.5	1,810	.0015	.002
October.						
1902	662	28	129	7,900	.006	.007
1903	22	9	16	984	.001	.001
1904	165	35	77	4,700	.004	.004
1905	131	34	69	4,200	.003	.004
1906	2,000	38	679	41,800	.033	.04
November.						
1902	75	28	37	2,200	.002	.002
1903 [d]	42	9	27	1,300	.....	.....
1904	270	35	109	6,500	.005	.006
1905	810	131	310	18,450	.015	.02
1906	1,850	1,200	1,550	49,200	.075	.04
December.						
1902 [e]	.....	.....	761	37,700	.037	.03
1904 [f]	360	140	263	7,800	.....	.....
1905	810	202	565	34,740	.027	.03

[a] 19 days in January.
[b] 18 days in February.
[c] 13 days in March.
[d] November 1 to 24.
[e] December 1 to 25.
[f] December 1 to 15.

SOUTH PLATTE RIVER AT BIG SPRING.

The station established at Big Spring, September 5, 1902, was abandoned November 21, 1903, as more reliable records could be obtained at Julesburg, Colo., 10 miles above.

Except during the winter months and flood periods there is no surface flow at this point. The bed at such times is a field of drifting sand, partly grown up with weeds. Gage heights were taken to the water surface obtained by digging in the sand at the gage.

The gage was of the wire and weight type and was attached to the upstream girder of the pile bridge near the left bank. The bench mark was a standard United States Geological Survey bench mark, 200 feet north of the Union Pacific depot; elevation, 5.15 feet above the zero of the gage, or 3,370 feet above sea level.

Discharge measurements of South Platte River at Big Spring, 1902–3.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
1902.		*Feet.*	*Sec.-ft.*	1903.		*Feet.*	*Sec.-ft.*
September 5	J. C. Stevens	1.00	0	April 1	J. C. Stevens	2.85	1,299
September 23	H. O. Smith	1.65	173	May 9	do	1.98	20
				July 8	do	1.80	Pools.
				July 28	do	1.80	2
				August 20	do	1.96	10

Mean daily gage height, in feet, of South Platte River at Big Spring, 1902–3.

Day.	Sept.	Oct.	Nov.	Day.	Sept.	Oct.	Nov.	Day.	Sept.	Oct.	Nov.
1902.				1902.				1902.			
1		1.80	1.45	12	1.00	1.35	1.35	23	1.65	1.35	1.30
2		1.80	1.45	13	1.00	1.35	1.30	24	1.50	1.25	1.30
3		1.80	1.45	14	1.00	1.35	1.30	25	2.00	1.25	1.30
4		1.80	1.45	15	1.00	1.30	1.30	26	2.40	1.20	1.35
5	1.00	1.60	1.40	16	1.00	1.35	1.30	27	2.15	1.25	1.35
6	1.05	1.60	1.30	17	1.10	1.35	1.30	28	1.90	1.25	1.30
7	1.00	1.60	1.25	18	1.10	1.25	1.30	29	1.80	1.25	1.45
8	1.00	1.50	1.25	19	1.15	1.25	1.30	30	1.80	1.25	.....
9	1.00	1.50	1.25	20	1.20	1.25	1.35	31	.....	1.35	.....
10	1.00	1.50	1.25	21	Pools.	1.20	1.30				
11	1.00	1.35	1.25	22	2.00	1.30	1.30				

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1903.									
1		2.90	2.00	2.00	1.80	1.85	1.90	2.00	2.12
2		2.95	2.00	2.00	1.75	1.85	1.85	2.00	2.15
3	3.75	2.65	2.00	2.00	1.85	1.80	1.85	2.00	.....
4		2.65	2.00	2.00	1.85	1.75	1.85	2.05	2.15
5		2.75	2.00	2.05	1.80	1.75	1.90	2.05	2.12
6		2.60	2.00	2.00	1.75	1.70	1.90	2.10	2.12
7		2.65	2.00	.....	1.85	1.70	1.90	2.05	2.12
8		2.65	1.95	.....	1.80	1.75	1.90	2.00	2.11
9		2.60	2.00	1.90	1.75	1.75	1.90	2.05	2.10
10	4.00	2.50	2.05	1.85	1.85	1.75	1.90	2.05	2.10
11	3.90	2.40	2.00	1.80	1.80	1.80	.....	2.05	2.15
12	3.90	2.40	2.00	1.80	1.80	1.80	1.90	2.10	2.10
13	3.75	2.40	1.75	1.80	1.80	1.75	1.90	2.10	2.12
14	3.55	2.00	1.80	1.80	1.90	1.75	1.90	2.13	2.13
15	3.25	2.30	1.75	1.80	1.80	1.70	1.90	2.11	2.10

Mean daily gage height, in feet, of South Platte River at Big Spring, 1902-3—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1903.									
16	3.25	2.00	1.75	1.80	1.80	1.85	1.90	2.10	2.10
17	2.80	2.00	1.80	1.80	1.80	2.45	1.90	2.10	.....
18	2.60	2.00	1.80	1.80	1.80	2.25	1.95	2.11	2.10
19	2.25	2.00	1.90	1.90	1.80	2.00	1.90	2.10	2.10
20	2.25	2.00	1.95	1.90	1.75	1.93	1.90	2.10	2.10
21	2.20	2.00	1.90	1.90	.....	1.85	.....	2.10	2.23
22	2.20	2.00	1.95	1.95	1.80	1.85	1.95	2.08	.....
23	2.20	2.00	1.95	1.95	1.80	2.25	1.95	2.07	.....
24	2.15	2.00	2.00	1.95	1.75	2.05	1.95	2.07	.....
25	2.15	2.75	2.00	1.90	1.75	2.00	1.95	2.11	.....
26	2.25	2.00	1.95	1.85	1.75	2.00	1.95	2.11	.....
27	2.20	2.00	1.95	1.85	1.80	2.13	1.95	2.15	.....
28	2.15	2.00	1.90	1.80	1.75	2.00	2.00	2.15	.....
29	2.20	3.20	2.00	1.80	1.75	2.00	2.00	2.16	.....
30	2.15	3.10	2.00	1.80	1.80	1.95	2.00	2.12	.....
31	2.15	.....	.....	.....	1.90	1.95	.....	2.12	.....

Mean daily discharge, in second-feet, of South Platte River at Big Spring, 1903.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	.....	1,380	20	20	.....	0	5	20	70
2	.....	1,470	20	20	.....	0	0	20	110
3	.....	930	20	20	0	.....	0	20	.....
4	.....	930	20	20	0	.....	0	40	110
5	.....	1,110	20	40	.....	.....	5	40	70
6	.....	840	20	20	.....	.....	5	70	70
7	.....	930	20	.....	0	.....	5	40	70
8	.....	930	10	.....	.....	.....	5	20	70
9	.....	840	20	5	.....	.....	5	40	70
10	.....	660	40	0	0	.....	5	40	70
11	.....	480	20	.....	.....	.....	.....	40	110
12	.....	480	20	.....	.....	.....	5	70	70
13	.....	480	0	.....	.....	.....	5	70	70
14	.....	20	0	.....	5	.....	5	110	110
15	.....	310	0	.....	.....	.....	5	70	70
16	.....	20	0	.....	.....	0	5	70	70
17	1,200	20	0	.....	.....	570	5	70	.....
18	840	20	0	.....	.....	230	10	70	70
19	230	20	5	5	.....	20	5	70	70
20	230	20	10	5	.....	10	5	70	70
21	160	20	5	5	.....	0	.....	70	230
22	160	20	10	10	.....	0	10	70	.....
23	160	20	10	10	.....	230	10	40	.....
24	110	20	20	10	.....	40	10	40	.....
25	110	1,110	20	5	.....	20	10	70	.....
26	230	20	10	0	.....	20	10	70	.....
27	160	20	10	0	.....	110	10	110	.....
28	110	20	5	.....	.....	20	20	110	.....
29	160	1,920	20	.....	.....	20	20	110	.....
30	110	1,740	20	.....	.....	10	20	70	.....
31	110	.....	.....	.....	5	10	.....	70	.....

LOUP RIVER DRAINAGE BASIN.

DESCRIPTION OF BASIN.

The Loup and its tributaries, as a system, form the most important feeders of the Platte and merit special description.

The stream is formed by three main branches, the North, Middle, and South Loup, which drain a broad area comprising 13,540 square miles, lying in the heart of Nebraska. In a former geologic age the three streams emptied into the Platte as separate and distinct tributaries; later the Platte, while building its bed, obstructed the flow of these streams by throwing sand across their mouths, forcing them to shift their channels eastward and down the Platte Valley until they united.

The Loup proper is formed by the junction of the North and Middle Loup near the city of St. Paul, the Middle Loup receiving the South Loup above this junction. The principal tributaries are Beaver, Cedar, Calamus, and Dismal rivers.

The drainage area as a whole is generally rolling, with scattered high plains or table-lands. The immediate valleys are composed of alluvial deposits of loam, sand, and gravel. Beyond the valleys the area is composed of yellow clays and fine sandy loam in the lower portions; in the upper portions sand hills abound. The soil is generally fertile, and large quantities of hay, grains, etc., are grown.

The streams are subject to a succession of floods during the spring and early summer, caused by melting snows and heavy rainfall during the spring months. As a large part of the area is grass grown, the evaporation is considerable, averaging 5 feet.

The North and Middle Loup drain an area of sand hills in which there are numerous lakes ranging in size from small ponds to lakes several square miles in area. Among them may be mentioned Stevenson Lake, Moon Lake, Pelican Lake, and Soda Lake. The region abounds in springs caused by the percolation of the precipitation through the sandy soil to the impervious clays below. This fact, no doubt, accounts for the remarkable constancy of flow of these streams. A comparatively small amount of the water is diverted for irrigation, the ditches generally being small and covering moderate areas. A number of power plants are in operation, and some others of considerable extent have been proposed, particularly one near Columbus by which it is believed that about 20,000 continuous horsepower may be developed. The gaging stations that have been maintained on these rivers are listed on page 35.

LOUP RIVER AT COLUMBUS.

The station at Columbus was established October 13, 1894. It is about 75 yards above the Union Pacific Railroad bridge and about 6 miles above the mouth of the river, in sec. 23, T. 17 N., R. 1 W., and is shown on the David City topographic atlas sheet.

The river is straight for about 1,000 feet above and a considerable distance below the cable section. The bed consists entirely of shifting sand. The left bank is high; the right is low and overflows at high water. There is but one channel at all stages. At the cable section the channel is free from obstructions, but owing to the swiftness of the water over the shifting sand the velocity of the current varies within wide limits, and hence it has been impossible to develop good rating curves. (See pp. 10–15.) At the lower gaging section the water runs mostly in a deep channel near the right bank and is obstructed by the piling of an old bridge a short distance below the existing highway bridge. Gage heights vary from 3 to 12 feet, excessive floods being very rare. The high gage heights are usually caused by ice gorges. Fairly successful attempts have been made to obtain records of winter flow, measurements being made through holes cut in the ice.

Discharge measurements are made from a cable having a span of about 600 feet and marked at intervals of 12½ feet. Some trouble has been experienced on account of the ice damages to the cable. When the cable was not in repair, measurements were made from the highway bridge, although the conditions there are not favorable for good results. Some of the estimates given are revisions of estimates heretofore published. The indirect method at best is only one of approximation, and where the results obtained by its use were inconsistent with actual gagings a slightly different method of interpolation between these gagings has been used.

Two gages have been maintained. One is a vertical staff spiked to piling at the cable; the other is a standard weight and chain gage at the highway bridge 1½ miles below the cable. The two gages were set to read the same height, but this relation has not been stable. The upper gage was used for daily observations from October 13, 1894, to June 24, 1904; since the later date the lower one has been used. The gages are referred to bench marks as follows: (1) A standard United States Geological Survey bench mark, 72 feet east of the upper gage; elevation, 21.83 feet above the zero of the lower gage and 13.27 feet above the zero of the upper gage. (2) A cross cut on the upstream end of the cap of the first bent at the north end of the highway-bridge approach; elevation, 10.91 feet above the zero of the lower gage.

Discharge measurements of Loup River at Columbus, 1895–1906.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*
1895.			
March 29	O. V. P. Stout	4.77	2,790
April 21	do	4.65	2,303
June 12	do	4.55	2,835
June 29	do	4.50	2,715
September 7	do	4.17	1,896
1896.			
March 15	do	3.88	1,550
May 3	Wm. Grant	5.12	4,256
June 4	O. V. P. Stout	4.76	3,222
June 24	do	4.10	3,206
July 22	E. T. Youngfelt	3.91	2,420
August 28	do	3.75	2,234
September 25	do	4.09	2,370
1897.			
March 19	Adna Dobson	5.22	6,307
March 23	do	4.85	3,869
April 27	do	4.53	2,972
April 27	do	4.53	3,103
May 25	do	4.77	2,572
May 25	do	4.77	2,410
June 17	O. V. P. Stout	4.72	2,818
July 16	do	4.01	2,513
July 29	do	3.87	1,660
August 17	do	4.27	1,783
August 29	do	4.21	1,436
October 7	Adna Dobson	4.19	1,926
October 30	do	4.70	4,580
November 21	do	4.40	3,006
1898.			
April 17	Glenn E. Smith	4.80	2,730
May 8	do	5.15	3,231
May 19	do	5.20	3,542
May 29	do	5.05	3,337
June 8	do	5.50	5,181
June 19	O. V. P. Stout	5.03	3,284
July 10	Glenn E. Smith	4.60	1,900
July 22	do	4.40	1,691
July 31	do	4.15	1,560
August 21	Adna Dobson	4.65	2,542
September 4	do	4.20	1,389
September 17	do	4.81	2,448
September 25	do	4.59	2,117
October 16	do	4.76	2,380
October 30	do	4.80	2,519
November 11	Glenn E. Smith	4.94	Ice.
November 20	do	4.90	2,862
1899.			
January 22	do	Frozen	2,726
April 9	do	4.95	3,004
April 23	do	5.00	2,699
May 7	do	5.05	3,057
May 23	do	5.54	4,073
June 4	do	4.86	2,628
June 18	do	4.75	1,921
June 29	do	5.80	7,728
July 9	do	5.40	3,435
July 23	do	4.25	1,792
August 6	do	4.93	3,251
August 20	do	4.61	2,267
September 3	do	4.40	1,902
September 17	do	4.40	1,840
October 5	do	4.60	2,402
October 15	do	4.80	1,983
1900.			
April 8	Adna Dobson	4.69	2,365
April 29	do	5.20	4,455
May 13	do	4.68	2,771
May 27	do	4.67	2,508
June 10	do	4.53	2,161
June 20	O. V. P. Stout	4.02	2,491
July 15	Adna Dobson	3.93	1,705
July 29	do	4.38	1,322
August 12	do	4.44	1,935
August 26	do	4.40	2,582
September 16	do	5.00	3,077
October 7	Adna Dobson	4.55	2,294
October 31	do	4.86	3,246
November 30	do	4.53	3,542
December 19	do	4.44	2,674
1901.			
March 31	do	4.65	3,134
April 21	do	4.85	3,242
May 10	do	4.85	2,615
June 7	B E Forbes	4.70	2,023
June 18	do	5.80	4,061
July 14	O. V. P. Stout	3.97	1,211
August 11	do	4.52	1,710
October 6	Frank Dobson	4.65	2,354
November 2	do	5.30	3,294
December 1	do	4.55	2,579
1902.			
March 8	do	5.79	6,826
April 13	do	4.76	2,532
May 11	do	4.81	2,206
May 22	J. C. Stevens	5.56	4,039
June 1	do	4.85	2,585
July 11	do	5.59	6,586
August 10	do	6.10	7,685
August 26	do	5.55	6,901
September 11	do	4.48	2,514
October 5	do	5.05	3,156
1903.			
March 20	do	5.10	6,074
April 3	do	5.00	3,905
May 7	do	5.10	3,409
June 11	do	5.12	3,432
June 27	do	5.05	2,799
July 10	do	4.67	3,022
July 17	do	5.56	5,022
August 1	do	6.78	14,580
August 18	do	5.13	4,177
September 19	do	4.49	2,644
September 29	do	4.40	2,328
October 30	do	4.61	2,607
December 20	do	6.50	2,280
1904.			
March 25	do	4.75	3,099
May 8	do	5.31	3,483
June 18	do	4.85	3,442
June 25	do	5.46	4,630
July 29	do	4.82	3,376
July 29	do	4.82	2,896
July 31	do	4.77	2,778
July 31	do	4.80	2,826
July 31	do	4.80	2,492
July 31	do	4.80	2,734
July 31	do	4.77	2,723
July 31	do	4.77	2,737
September 2	O. H. Timmerman.	5.01	2,880
1905.			
March 17	H. C. Gardner	4.40	4,659
May 4	do	4.55	4,982
May 16	do	5.90	12,890
June 21	do	4.65	5,316
July 8	do	5.30	9,263
July 14	do	4.80	4,126
August 12	do	4.20	5,089
September 27	F. S. Dobson	4.03	3,153
October 13	do	4.18	4,113
1906.			
February 23	do	5.95	11,290
March 30	Geo. W. Bates	5.60	7,619
May 3	do	5.84	9,321
June 8	Arthur Dobson	4.39	2,755
July 13	do	4.25	2,248
August 28	do	4.65	2,813
September 29	do	4.49	2,686
October 27	do	4.63	3,758
November 24	do	4.70	2,751

Mean daily discharge, in second-feet, of Loup River at Columbus, 1895–1906.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1895.									
1	.....	3,070	2,840	4,330	2,822	1,525	3,011	2,239	2,562
2	.....	3,000	4,360	4,000	2,849	1,546	2,875	2,144	2,613
3	.....	2,670	4,420	9,080	2,613	1,546	2,410	2,004	2,664
4	.....	2,660	3,590	7,190	2,562	4,104	2,191	1,913	2,822
5	.....	2,700	3,290	5,580	2,588	1,588	2,191	2,312	2,928
6	.....	2,520	3,180	4,775	2,562	2,264	1,957	2,288	2,822
7	.....	2,675	2,930	3,800	2,434	1,957	1,913	2,433	2,875
8	.....	3,675	2,850	3,420	2,240	1,891	1,935	2,337	2,955
9	.....	3,450	2,750	3,010	2,288	1,846	2,027	2,288	3,011
10	.....	3,320	2,675	2,780	2,027	2,074	1,913	2,433	3,011
11	.....	3,150	2,690	2,900	2,074	2,562	1,891	2,488	3,067
12	.....	2,950	2,800	2,835	2,051	2,408	1,758	2,434	3,132
13	.....	2,780	2,740	3,176	1,980	1,891	1,736	2,485	3,178
14	.....	2,840	2,700	3,384	2,361	1,980	1,673	2,485	3,292
15	.....	2,625	2,600	2,205	2,562	2,743	1,736	2,562	3,378
16	.....	2,650	2,620	2,822	2,337	2,796	1,715	2,690	3,523
17	.....	2,875	2,710	3,205	2,191	2,280	1,957	2,536	3,643
18	.....	2,890	2,770	4,264	2,074	2,288	2,074	2,460	3,378
19	.....	2,725	2,820	4,296	2,004	2,191	2,121	2,485	3,095
20	.....	2,650	2,830	3,350	1,980	2,240	2,121	2,536	2,928
21	.....	2,303	2,730	3,039	1,824	2,191	2,822	2,485	2,822
22	.....	2,400	2,820	2,562	1,736	2,097	3,793	2,562	2,875
23	.....	2,500	2,850	3,011	1,758	2,434	3,465	2,113	2,690
24	.....	2,520	2,800	2,850	1,846	2,743	4,264	2,636	.....
25	.....	2,450	2,880	2,337	1,957	2,902	4,995	2,390	.....
26	.....	2,440	2,740	2,361	1,935	2,664	2,849	2,690	.....
27	.....	2,440	2,750	2,337	2,004	2,264	2,536	2,613	.....
28	.....	2,490	2,750	2,588	1,588	2,536	2,337	2,511	.....
29	.....	2,640	2,650	2,562	1,567	2,460	2,239	2,434	.....
30	.....	2,550	3,350	2,690	1,523	2,313	2,312	2,536	.....
31	.....	.....	3,470	.....	1,446	2,613	.....	3,613	.....
1896.									
1	.....	3,205	4,807	2,694	2,817	3,100	2,063	2,402	.....
2	.....	3,558	4,220	3,126	2,694	3,203	2,150	2,380	.....
3	.....	3,205	4,220	3,153	2,832	3,258	2,264	2,287	.....
4	.....	2,945	3,897	3,205	2,792	3,258	2,455	2,287	.....
5	.....	3,126	3,312	3,613	2,670	3,021	2,430	2,240	.....
6	.....	3,048	3,390	.....	2,597	2,868	2,287	2,287	.....
7	.....	3,126	3,048	.....	2,500	3,811	2,170	2,358	.....
8	.....	3,205	2,768	8,000	2,572	3,338	2,063	2,477	.....
9	.....	3,338	2,694	3,441	2,768	2,668	2,063	2,548	.....
10	.....	3,393	2,743	3,073	2,621	2,620	2,170	2,548	.....
11	.....	3,365	2,867	1,991	3,670	2,620	2,287	2,694	.....
12	.....	4,430	2,621	2,203	3,258	2,384	2,572	2,817	.....
13	.....	6,950	2,728	2,063	3,048	2,429	2,694	2,817	.....
14	.....	5,795	2,892	2,086	2,892	2,482	2,867	2,768	.....
15	.....	4,650	2,645	2,106	2,525	2,429	2,968	2,832	.....
16	.....	3,725	3,022	2,180	2,334	2,382	2,968	2,743	.....
17	.....	4,160	3,022	2,106	2,334	2,288	2,832	2,645	.....
18	.....	4,650	2,945	1,991	2,310	2,382	2,694	2,645	.....
19	.....	7,018	2,892	1,928	2,406	2,406	2,548	2,621	.....
20	.....	5,938	2,892	2,406	2,406	2,454	2,597	2,597	.....
21	.....	5,157	2,832	2,867	2,455	2,502	2,645	2,817	.....
22	.....	4,017	2,670	3,338	2,420	2,454	2,670	2,918	.....
23	.....	5,032	2,621	3,725	2,482	2,596	2,728	2,945	.....
24	.....	5,060	2,455	3,258	2,482	2,596	2,524	3,022	.....
25	.....	3,205	2,358	4,160	2,596	2,502	2,370	2,945	.....
26	.....	3,126	2,310	4,494	2,727	2,358	2,334	2,968	.....
27	.....	3,100	2,621	3,021	2,945	2,288	2,370	3,022	.....
28	.....	5,326	2,645	2,743	2,970	2,264	2,406	2,832	.....
29	.....	3,613	2,867	2,670	2,970	2,264	2,310	3,022	.....
30	.....	1,970	2,917	2,621	2,970	2,180	2,287	3,585	.....
31	.....	.....	2,621	.....	3,021	2,106	.....	3,613	.....
1897.									
1	.....	.....	2,750	1,975	11,825	1,600	1,350	1,600	.....
2	.....	.....	2,675	1,800	5,350	1,450	1,275	1,650	.....
3	.....	7,125	2,850	1,800	3,525	1,350	1,175	1,675	.....
4	.....	.....	2,850	2,675	3,300	1,275	1,175	1,675	.....
5	.....	.....	2,850	2,350	3,050	1,675	1,050	1,750	.....

Mean daily discharge, in second-feet, of Loup River at Columbus, 1895–1906—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1897.									
6	.....	.....	2,800	2,675	2,975	2,500	1,075	1,800	.....
7	.....	.....	2,750	2,500	2,025	2,225	1,150	1,900	.....
8	.....	3,950	2,775	2,500	1,750	2,400	1,000	1,925	.....
9	.....	3,650	2,775	2,500	1,650	3,025	1,075	1,975	.....
10	.....	3,450	2,875	2,425	1,850	3,050	1,350	2,075	.....
11	.....	3,075	2,675	2,425	2,075	3,275	1,525	2,350	.....
12	.....	2,775	2,675	2,600	2,375	2,725	1,625	2,725	.....
13	.....	3,825	2,575	2,800	2,300	2,500	1,650	2,825	.....
14	.....	4,100	2,525	2,775	2,225	2,375	1,625	2,850	.....
15	.....	3,625	2,525	2,850	2,975	2,125	1,625	2,950	.....
16	.....	3,500	2,500	2,850	2,650	1,950	1,550	3,125	.....
17	.....	3,675	2,425	2,850	2,050	1,800	1,700	3,375	.....
18	.....	4,075	2,375	2,775	2,050	1,600	1,550	4,700	.....
19	.....	3,250	2,350	3,150	1,850	1,500	1,475	4,800	.....
20	.....	3,225	2,225	3,000	2,250	1,450	1,450	4,375	.....
21	.....	3,275	2,250	2,575	2,325	1,425	1,425	4,325	.....
22	.....	3,950	2,300	2,350	2,150	1,275	1,450	4,250	.....
23	.....	3,800	2,500	2,200	2,075	1,325	1,475	4,200	.....
24	.....	3,575	2,575	2,175	2,050	1,300	1,550	4,500	.....
25	.....	3,550	2,000	2,275	1,975	1,275	1,600	4,250	.....
26	.....	3,375	2,225	2,525	1,975	1,325	1,625	4,200	.....
27	.....	3,050	2,100	9,550	1,850	1,200	1,600	4,800	.....
28	.....	2,725	2,300	4,000	1,650	1,100	1,550	10,400	.....
29	.....	2,675	2,175	3,600	1,625	1,275	1,550	4,875	.....
30	.....	3,040	2,025	4,250	1,600	1,300	1,550	4,750	.....
31	.....	.....	1,850	.....	1,725	1,425	.....	.....	.....
1898.									
1	.....	2,130	2,425	3,375	2,025	1,650	1,800	2,025	2,800
2	.....	2,730	2,425	3,300	2,025	1,725	1,715	2,075	2,675
3	.....	2,700	2,550	3,525	1,925	1,820	1,620	2,080	2,550
4	.....	2,730	3,075	3,900	1,975	2,600	1,600	2,225	2,450
5	.....	2,800	3,775	5,600	2,425	3,450	1,575	2,175	2,450
6	.....	2,850	3,625	6,675	2,530	1,725	1,520	2,200	2,550
7	.....	2,960	3,530	5,750	2,400	4,720	1,500	2,225	2,550
8	.....	2,850	3,400	5,600	2,400	3,500	1,500	2,200	2,675
9	.....	2,700	3,300	5,375	2,200	3,175	1,460	2,325	2,800
10	.....	2,820	3,175	5,000	2,025	2,900	1,600	2,375	2,800
11	.....	2,800	3,350	4,600	2,075	2,725	1,620	2,600	2,900
12	.....	2,960	3,425	4,325	2,050	2,625	1,700	2,900	2,825
13	.....	2,860	3,282	4,450	2,000	2,550	2,470	2,725	.....
14	.....	3,520	3,050	4,550	2,100	2,460	2,950	2,500	.....
15	.....	3,375	2,700	4,600	2,100	2,440	2,730	2,425	.....
16	.....	3,125	2,800	4,450	2,050	2,475	2,650	2,400	.....
17	.....	2,820	2,850	4,400	2,025	2,675	2,700	2,425	.....
18	.....	2,675	3,375	4,050	1,865	3,050	2,490	2,450	.....
19	.....	3,150	3,175	4,050	1,780	2,950	2,490	2,650	.....
20	.....	3,050	3,500	4,100	1,700	2,675	2,350	2,800	.....
21	.....	3,150	4,150	4,325	1,725	2,550	2,200	2,650	.....
22	.....	2,550	4,250	4,550	1,700	2,600	1,870	2,550	.....
23	.....	2,425	4,400	4,100	1,825	2,530	1,700	2,525	.....
24	.....	2,400	5,100	3,025	1,650	2,500	1,925	2,425	.....
25	.....	2,520	4,200	2,425	1,820	2,490	2,080	2,775	.....
26	.....	2,775	4,975	2,275	1,630	2,490	2,080	2,525	.....
27	.....	2,630	4,450	2,175	1,680	2,490	2,080	2,725	.....
28	.....	2,600	4,150	2,120	1,680	2,300	2,075	2,725	.....
29	.....	2,650	3,525	2,000	1,700	2,050	2,025	2,650	.....
30	.....	2,500	3,550	2,100	1,750	1,950	2,025	2,550	.....
31	.....	.....	3,250	.....	1,680	1,850	.....	2,900	.....
1899.									
1	.....	.....	3,586	.....	6,289	1,805	2,793	1,933	.....
2	.....	4,251	2,694	2,945	.....	1,702	2,945	1,933	.....
3	.....	4,871	1,911	.....	6,984	1,581	2,819	1,954	.....
4	.....	5,526	2,152	2,646	.....	1,682	2,819	1,954	.....
5	.....	5,195	2,646	.....	5,459	2,312	2,573	1,945	.....
6	.....	3,127	2,768	4,043	.....	3,258	2,335	1,911	.....
7	.....	2,869	3,047	.....	4,191	3,153	2,220	1,890	.....
8	.....	3,127	2,793	.....	.....	2,894	2,085	1,825	.....
9	.....	2,995	3,312	.....	.....	2,995	2,793	1,764	.....
10	.....	2,869	2,894	.....	1,188	2,869	2,549	1,682	.....

Mean daily discharge, in second-feet, of Loup River at Columbus, 1895–1906—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1899.									
11		3,100	2,743	3,727	.....	2,597	2,312	1,581	.....
12		2,819	2,359	.....	1,000	2,970	2,085	1,445	.....
13		2,549	2,453	.....	1,000	1,484	1,975	1,315	.....
14		2,768	2,694	.....	1,000	1,278	1,847	1,581	.....
15		3,258	3,530	.....	1,082	2,063	1,847	1,954	.....
16		3,476	3,100	2,040	1,014	1,445	1,847	1,784	.....
17		3,285	3,049	.....	1,315	1,825	1,847	1,954	.....
18		3,100	2,549	1,804	1,334	1,868	1,847	1,911	.....
19		2,793	2,646	.....	1,135	2,018	1,868	1,764	.....
20		2,500	2,768	.....	1,170	2,265	1,868	1,620	.....
21		2,476	3,670	2,743	1,260	2,719	1,868	1,682	.....
22		2,453	4,871	.....	1,465	2,476	1,868	2,175	.....
23		2,694	4,072	.....	1,784	2,622	1,890	2,018	.....
24		2,453	3,699	3,985	1,682	2,743	1,890	2,085	.....
25		2,336	.....	.....	1,702	2,768	1,890	2,040	.....
26		2,476	.....	7,287	1,661	2,743	1,910	2,108	.....
27		2,743	.....	.....	1,661	2,793	1,911	2,153	.....
28		3,811	.....	7,713	1,682	2,768	1,911	2,085	.....
29		4,131	3,869	.....	1,702	2,524	1,911	2,242	.....
30		5,064	.....	.....	2,265	2,312	1,933	2,500	.....
31		.....	.....	.....	2,040	2,549	.....	2,524	.....
1900.									
1		2,380	4,130	2,920	2,320	2,230	2,575	2,900	2,875
2		2,380	3,811	2,549	3,860	2,300	2,610	2,930	2,790
3		2,380	3,642	2,085	2,460	2,090	2,650	3,010	2,650
4		2,380	3,670	2,920	4,235	2,075	2,500	3,050	2,390
5		2,380	3,699	2,970	3,410	2,075	2,600	3,100	2,400
6		2,380	3,586	2,844	5,380	2,125	2,490	3,150	2,350
7		2,380	3,670	2,670	3,860	1,610	2,440	3,300	2,300
8		2,406	4,650	2,430	4,300	1,800	2,450	3,300	2,375
9		2,430	4,557	2,197	4,550	3,175	2,400	3,352	2,450
10		2,548	3,670	2,154	3,615	3,350	2,375	3,400	2,550
11		2,546	3,503	3,375	3,490	3,050	7,600	3,350	2,750
12		2,597	3,476	3,450	3,050	2,800	4,600	3,300	2,820
13		2,894	5,729	3,535	2,900	2,900	5,510	3,250	2,975
14		2,945	4,161	3,650	2,490	2,850	6,090	3,240	2,900
15		2,945	3,985	4,060	2,370	3,419	5,510	3,175	2,940
16		3,048	3,699	4,350	3,200	6,290	4,000	3,125	2,870
17		3,153	3,614	14,300	4,150	6,700	3,150	3,020	3,150
18		3,232	3,558	6,650	4,210	7,480	2,650	2,975	.....
19		3,367	3,563	5,615	3,740	6,200	2,680	3,020	.....
20		3,670	3,340	3,075	3,120	3,300	5,510	3,100	.....
21		4,588	2,793	2,985	2,820	3,220	2,710	3,100	.....
22		4,619	2,719	3,355	2,800	3,200	2,790	3,200	.....
23		4,650	2,670	2,700	2,700	3,100	2,850	3,200	.....
24		4,744	2,646	2,715	3,900	3,220	2,820	3,300	.....
25		4,619	2,382	2,575	4,030	3,710	2,850	3,400	.....
26		4,619	2,476	2,690	3,775	3,950	2,870	3,500	.....
27		4,619	3,073	2,575	2,150	4,310	2,930	3,600	.....
28		4,619	2,814	2,520	2,350	4,230	2,900	3,700	.....
29		4,464	2,869	2,500	2,000	3,750	2,930	3,675	.....
30		4,464	2,573	2,390	1,980	3,200	2,790	3,175	.....
31		.....	10,550	.....	2,000	2,955	.....	3,020	.....
1901.									
1		2,694	2,549	1,847	3,048	1,206	1,763	2,220	2,335
2		2,646	2,500	1,825	2,970	1,082	1,763	2,336	3,294
3		2,670	2,453	1,825	2,743	1,064	1,784	2,360	3,367
4		2,919	2,406	2,018	2,793	1,047	1,932	2,358	3,126
5		3,153	2,359	2,243	2,844	1,031	2,220	2,354	2,818
6		3,394	2,573	2,023	2,406	1,064	2,453	2,324	2,670
7		2,719	2,548	2,023	1,890	1,047	2,720	2,354	2,452
8		2,597	2,621	2,023	1,784	1,031	2,844	2,336	2,242
9		2,573	2,743	2,023	1,661	1,000	2,844	2,430	1,825
10		2,819	2,615	1,975	1,523	1,000	3,258	2,647	1,743
11		3,048	2,500	1,763	1,389	1,710	3,258	2,622	1,763
12		3,285	2,476	1,743	1,426	1,484	4,251	2,600	1,800
13		3,840	2,476	1,743	1,445	1,291	4,588	2,574	1,840
14		4,101	2,243	1,723	1,211	1,582	4,744	2,550	1,997
15		4,402	2,220	1,723	1,170	1,484	4,744	2,524	1,932

Mean daily discharge, in second-feet, of Loup River at Columbus, 1895–1906—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1901.									
16	.....	4,681	2,197	7,097	1,241	1,484	4,776	2,382	1,974
17	.....	4,342	1,975	7,097	1,223	1,484	4,161	2,242	2,017
18	.....	3,754	1,975	4,861	1,206	1,381	3,868	2,200	2,059
19	.....	3,727	1,954	5,195	1,188	1,311	3,339	2,062	2,101
20	.....	3,699	2,062	5,526	1,260	1,260	2,359	2,019	2,152
21	.....	3,242	2,152	5,902	1,911	1,260	2,359	1,975	2,196
22	.....	3,258	2,383	5,729	1,681	1,260	2,483	1,953	2,240
23	.....	3,100	2,243	5,593	1,485	1,323	2,483	1,921	2,285
24	2,995	3,048	2,359	5,293	1,260	1,523	2,406	1,898	2,332
25	2,995	2,768	2,476	4,681	1,064	2,152	2,172	1,997	2,382
26	2,995	3,258	2,573	4,402	1,000	1,825	1,975	1,997	2,429
27	2,743	2,719	2,573	3,985	1,000	1,794	1,975	1,975	2,477
28	2,743	3,179	2,312	3,783	1,014	1,640	1,975	1,953	2,646
29	2,743	3,153	2,312	3,232	1,000	1,640	1,975	1,930	2,696
30	2,621	2,844	2,063	3,126	1,153	1,640	2,106	2,040	2,869
31	3,134	.....	1,847	.....	1,315	1,640	.....	2,359	.....
1902.									
1	.....	2,382	2,298	2,585	7,363	3,530	6,040	3,152	2,477
2	.....	2,243	2,298	2,869	9,936	3,258	5,000	3,126	2,500
3	.....	2,130	2,265	3,047	10,895	2,970	3,476	3,100	2,500
4	.....	1,976	2,382	4,151	7,910	2,970	3,224	3,048	2,622
5	.....	2,175	2,500	5,425	7,990	2,695	2,995	2,819	2,622
6	.....	2,646	2,743	5,763	7,871	2,695	2,671	2,869	2,622
7	.....	2,382	2,970	5,936	8,152	2,573	2,743	2,869	2,743
8	6,826	2,382	2,719	3,047	7,830	2,463	2,406	2,743	2,869
9	6,760	2,382	2,573	2,793	7,517	4,043	2,382	2,500	2,869
10	4,101	2,382	2,464	2,585	9,892	1,685	2,335	2,500	2,869
11	3,232	2,359	2,203	2,359	6,586	3,698	2,514	2,995	2,500
12	2,945	2,405	2,203	2,265	5,326	3,125	2,382	4,712	2,265
13	3,178	2,532	2,382	2,298	4,526	3,100	2,265	4,402	2,155
14	3,355	2,405	2,824	2,211	5,146	3,073	2,220	4,101	2,155
15	3,285	2,405	3,367	2,265	5,277	3,073	2,063	3,811	2,155
16	3,258	2,265	3,367	2,500	4,712	3,125	1,911	3,530	2,040
17	2,995	2,265	3,340	2,479	4,657	3,203	1,693	3,250	2,155
18	2,970	2,265	4,493	2,500	4,712	4,402	2,062	2,995	2,265
19	2,660	2,243	5,129	3,421	4,691	6,255	2,265	2,743	2,383
20	2,621	2,221	5,763	4,650	4,372	6,183	2,597	2,743	2,500
21	2,645	2,221	7,443	3,503	4,043	6,255	2,909	2,743	2,500
22	2,645	2,311	4,039	3,394	3,727	6,005	5,867	2,743	2,500
23	2,693	2,358	3,869	2,768	3,558	6,075	6,909	2,743	2,525
24	2,719	2,334	3,755	3,047	3,394	5,867	3,586	2,743	2,622
25	2,945	2,311	3,503	2,824	3,690	6,724	3,530	2,743	2,622
26	3,152	2,464	4,372	2,621	3,718	6,901	3,530	2,743	2,622
27	3,285	3,206	2,695	3,179	3,586	6,541	4,402	2,743	2,622
28	3,312	3,047	2,597	3,258	3,727	6,614	3,783	2,522	2,622
29	3,366	2,793	2,500	3,840	3,699	6,901	3,476	2,622	2,622
30	2,793	2,793	2,429	3,927	3,699	6,725	3,312	2,500	.....
31	2,500	.....	2,524	.....	3,530	8,152	.....	2,500	.....
1903.									
1	.....	3,890	3,890	6,060	2,740	13,750	3,400	2,380	2,620
2	.....	3,550	3,890	5,180	2,260	12,750	3,130	2,380	2,620
3	.....	4,300	3,890	4,740	2,500	5,180	2,870	2,380	2,870
4	.....	3,890	3,890	4,520	15,750	3,890	2,620	2,500	2,870
5	.....	3,890	3,550	4,300	12,750	3,000	2,380	2,500	2,870
6	.....	3,710	3,550	3,890	6,750	2,740	2,380	2,620	2,870
7	.....	3,890	3,400	3,890	3,890	2,500	3,400	2,620	2,870
8	.....	3,890	3,550	3,890	3,710	2,260	3,130	2,620	2,870
9	.....	4,300	3,550	3,890	3,000	2,260	2,870	2,500	2,870
10	.....	4,520	3,550	3,710	3,000	2,260	2,870	2,500	2,740
11	.....	4,520	4,520	3,260	2,870	2,740	3,130	2,740	2,740
12	.....	4,090	6,500	3,000	2,260	3,260	3,130	2,740	2,740
13	8,250	3,710	5,840	2,870	2,150	5,180	3,130	3,130	2,740
14	7,400	4,520	4,740	2,620	2,150	10,750	3,550	3,710	2,870
15	6,500	4,740	3,710	2,620	5,180	8,750	3,260	3,550	2,870
16	6,500	4,090	3,710	2,500	6,750	3,890	3,000	3,260	3,130
17	6,750	3,890	3,710	2,500	4,960	4,090	2,740	3,260	3,710
18	6,500	4,300	3,260	2,260	3,710	3,550	2,500	3,000	4,520
19	6,280	4,300	3,260	2,150	3,260	3,260	2,740	3,000	4,960
20	6,060	4,740	2,870	2,150	3,130	2,740	2,620	3,000	4,960

Mean daily discharge, in second-feet, of Loup River at Columbus, 1895–1906—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1903.									
21	5,180	4,740	3,000	2,150	2,740	2,500	2,620	2,870	5,400
22	4,520	4,300	3,260	2,380	2,500	2,260	2,380	2,870	5,620
23	4,520	3,890	3,400	2,380	2,260	2,260	2,380	2,870	5,620
24	4,740	4,300	4,960	2,260	2,040	2,260	2,380	2,870	5,400
25	4,300	3,710	4,300	2,620	2,040	2,500	2,380	2,740	5,840
26	4,090	3,550	4,090	2,740	2,040	3,000	2,380	2,740	4,300
27	4,090	3,400	3,400	2,870	2,040	20,000	2,380	2,740	3,710
28	4,090	3,400	4,300	2,870	2,040	16,750	2,380	2,620	3,400
29	5,180	3,400	5,400	2,740	2,260	7,050	2,380	2,740	.....
30	5,180	3,400	5,620	2,620	5,180	5,620	2,380	2,620	.....
31	5,400	.....	6,060	.....	4,300	3,550	.....	2,620	.....
1904.									
1	.....	3,550	2,740	2,500	2,740	2,150	2,740	3,260	1,740
2	.....	3,400	2,500	2,740	2,740	2,150	2,870	4,090	1,740
3	.....	3,400	2,500	3,710	2,740	2,620	4,960	3,890	1,660
4	.....	3,260	2,620	3,890	2,870	3,000	3,400	3,710	1,740
5	.....	3,260	2,500	4,090	3,000	3,000	3,000	3,260	1,740
6	.....	3,400	2,620	3,890	6,060	3,000	2,150	2,620	1,510
7	.....	3,550	3,000	3,400	7,050	2,870	2,150	2,150	1,740
8	.....	4,300	3,400	3,400	9,250	3,000	2,150	2,150	1,930
9	.....	3,710	3,400	3,890	6,060	3,890	1,930	2,260	1,930
10	.....	3,550	3,260	20,000	11,750	3,710	1,820	2,870	2,040
11	.....	3,400	3,130	6,060	9,250	2,620	1,660	2,620	2,040
12	.....	3,400	3,130	5,400	4,520	2,380	1,820	3,000	2,040
13	5,400	3,260	3,130	4,960	3,000	2,150	1,820	2,740	2,040
14	5,400	3,000	3,130	7,400	2,620	2,040	1,820	2,500	1,930
15	5,180	3,000	3,130	5,400	2,380	1,820	3,260	2,500	2,040
16	4,300	3,000	3,000	4,520	2,150	1,820	2,040	2,380	2,040
17	3,890	3,000	2,870	3,890	2,380	1,930	1,930	2,260	2,040
18	3,710	3,000	2,870	3,400	10,250	2,150	1,740	3,260	2,150
19	3,550	3,000	2,870	3,400	3,550	2,380	1,930	9,750	2,040
20	3,400	3,130	3,000	3,000	3,550	2,500	1,820	7,800	2,260
21	3,260	3,260	3,000	3,130	3,550	2,740	2,040	3,000	2,150
22	3,260	3,260	3,000	2,620	6,500	2,150	2,260	2,500	2,150
23	3,260	3,260	3,000	2,150	2,740	1,740	2,760	2,500	2,150
24	3,260	3,400	3,000	2,380	2,500	2,660	2,040	1,930	2,500
25	3,130	4,300	4,750	4,300	2,500	1,660	2,260	1,820	1,820
26	3,130	4,090	6,500	4,520	2,740	1,660	2,260	1,660	1,820
27	3,130	3,550	3,130	3,890	2,620	1,660	2,260	1,740	.....
28	3,260	3,000	2,870	3,260	3,260	1,660	2,740	1,660	.....
29	3,260	2,870	1,930	3,000	2,620	1,660	3,000	1,740	.....
30	3,260	2,740	1,930	2,740	2,500	1,740	3,130	1,820	.....
31	3,550	.....	2,040	.....	2,820	3,260	.....	1,740	.....
1905.									
1	.....	3,950	5,400	8,700	19,020	6,700	5,000	3,180	3,670
2	.....	4,400	5,150	7,500	15,120	19,190	4,700	3,910	3,450
3	.....	4,900	5,900	10,500	18,050	13,600	4,420	3,750	3,210
4	.....	6,950	5,400	7,500	17,080	8,270	4,380	3,580	3,210
5	.....	5,400	6,150	5,900	12,600	7,000	5,300	3,200	3,900
6	.....	4,400	6,675	5,650	11,700	5,300	5,770	3,250	5,100
7	.....	3,500	6,400	4,175	12,300	5,700	7,000	3,300	4,380
8	.....	3,050	5,900	3,725	9,900	6,110	6,960	3,350	4,110
9	.....	3,500	6,150	4,650	8,370	5,720	5,300	3,880	4,110
10	.....	3,950	11,100	4,175	6,750	5,600	5,010	3,940	4,380
11	.....	3,950	7,500	5,400	6,050	5,750	4,700	4,000	4,380
12	.....	3,500	6,950	5,400	5,400	5,600	4,410	4,070	4,600
13	.....	3,500	12,300	5,150	4,270	5,550	4,600	4,350	4,600
14	.....	3,950	15,780	4,650	2,900	5,250	7,110	4,600	4,850
15	.....	4,400	19,350	4,900	5,220	5,450	10,250	4,600	4,380
16	.....	3,950	12,300	5,400	5,100	6,700	8,400	5,600	4,380
17	4,400	3,950	9,900	5,900	4,730	6,110	6,950	5,100	4,380
18	5,400	3,950	7,500	5,400	4,650	6,850	8,580	4,850	4,850
19	5,900	3,500	7,225	5,400	4,800	12,100	14,600	5,330	4,600
20	6,950	11,100	6,950	5,900	4,920	6,200	8,710	4,850	4,600
21	5,900	8,700	6,950	6,675	5,310	6,150	6,130	4,110	4,380
22	5,900	8,400	6,400	7,500	5,460	8,000	5,050	4,600	4,110
23	5,400	8,100	6,150	16,100	6,130	6,300	3,810	4,380	5,850
24	4,400	7,800	5,650	16,750	7,400	6,500	3,310	3,670	5,350
25	4,900	7,500	5,400	11,400	6,430	7,000	3,950	3,670	5,850

Mean daily discharge, in second-feet, of Loup River at Columbus, 1895–1906—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1905.									
26	4,900	7,225	6,950	8,700	25,800	6,110	2,400	3,670	5,100
27	5,400	7,225	7,225	7,225	15,450	6,050	3,150	3,670	5,600
28	4,400	7,225	8,100	19,350	9,450	5,230	3,000	3,900	5,100
29	3,950	6,950	19,680	20,000	8,430	5,170	3,050	4,380	2,600
30	3,500	5,900	14,150	13,820	7,320	5,100	3,120	3,900	2,600
31	3,950	.....	12,000	.....	4,970	5,050	.....	3,900	.....
1906.									
1	.....	.....	25,000	3,400	7,900	4,000	1,400	2,300	3,300
2	.....	.....	14,100	2,800	4,400	3,600	1,700	2,100	3,500
3	.....	.....	18,700	3,000	3,900	2,700	2,200	2,200	4,100
4	.....	.....	8,700	3,200	2,600	4,200	2,000	2,400	4,600
5	.....	.....	7,200	3,000	2,400	5,000	2,000	2,100	4,900
6	.....	.....	4,500	3,200	2,200	4,400	2,000	2,100	4,900
7	.....	.....	4,500	3,200	2,100	11,600	1,800	2,100	4,600
8	.....	3,650	4,300	2,800	2,100	9,000	1,800	1,900	3,400
9	.....	3,950	3,400	2,800	2,100	6,600	1,700	1,900	3,200
10	.....	3,500	1,900	2,600	1,900	6,200	1,100	2,000	3,600
11	.....	2,900	1,900	2,200	1,900	3,300	1,400	2,400	2,700
12	.....	2,500	1,500	2,000	1,700	2,700	1,700	2,400	2,000
13	.....	3,600	2,000	2,000	2,100	2,900	2,700	2,400	2,500
14	.....	6,600	1,800	2,200	2,800	2,900	7,400	2,500	2,400
15	.....	8,700	1,800	2,600	2,100	2,100	4,400	2,200	2,200
16	.....	4,000	1,800	2,600	2,200	1,900	3,500	2,900	2,200
17	.....	4,500	1,600	2,400	2,100	1,800	5,400	2,500	2,000
18	.....	4,200	1,600	2,600	2,200	1,600	3,700	3,100	2,400
19	.....	7,200	1,600	2,800	3,600	1,400	3,400	3,100	2,200
20	.....	7,200	1,600	2,400	2,800	1,300	2,200	3,500	2,200
21	.....	4,000	1,600	2,200	3,600	1,300	2,600	3,700	.....
22	.....	3,800	2,000	2,200	2,600	1,000	2,400	5,700	.....
23	.....	3,600	2,700	1,900	2,800	1,000	2,400	5,700	.....
24	.....	3,600	2,900	2,200	2,800	1,000	2,600	7,100	2,750
25	.....	3,400	5,400	2,800	2,400	1,000	2,600	5,600	2,750
26	.....	3,600	4,100	3,800	2,000	1,900	2,600	4,300	2,900
27	.....	8,100	4,500	4,800	3,600	2,800	2,500	3,600	3,100
28	.....	11,000	4,800	4,600	2,000	2,800	2,300	5,300	3,100
29	.....	8,700	3,600	4,800	3,200	1,700	2,300	3,400	3,100
30	.....	16,100	6,900	3,700	3,100	1,500	2,300	4,800	2,900
31	.....	.....	4,300	.....	2,900	1,500	.....	4,300	.....

Mean daily gage height, in feet, of Loup River at Columbus, 1894–1906.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1894.				1894.				1894.			
1	.....	4.66	5.00	12	.....	4.82	4.80	23	4.65	4.85	4.72
2	.....	4.65	4.72	13	.....	4.65	4.82	24	4.65	4.80	4.71
3	.....	4.67	4.72	14	4.7	4.78	4.83	25	4.70	4.73	4.65
4	.....	4.75	4.76	15	4.65	4.74	4.75	26	4.65	4.67	4.54
5	.....	4.77	4.72	16	4.65	4.57	4.77	27	4.60	4.72	4.52
6	.....	4.73	4.71	17	4.60	4.73	4.81	28	4.65	4.68	4.78
7	.....	4.70	4.72	18	4.60	4.71	4.80	29	4.67	4.81	4.78
8	.....	4.72	4.67	19	4.60	5.00	4.83	30	5.00	4.78	4.94
9	.....	4.78	4.63	20	4.65	4.63	4.75	31	4.10	.....	5.4
10	.....	4.76	4.72	21	4.65	4.74	4.75				
11	.....	5.00	4.75	22	4.65	4.83	4.63				

Mean daily gage height, in feet, of Loup River at Columbus, 1894–1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1895.												
1	5.10	6.10	6.75	4.95	4.80	5.27	4.55	4.01	4.62	4.31	4.46	5.10
2	5.23	6.10	5.69	4.92	5.44	5.15	4.56	4.01	4.56	4.28	4.47	5.33
3	5.31	6.15	4.75	4.75	5.47	7.10	4.47	4.01	4.38	4.21	4.49	5.47
4	5.21	6.24	3.89	4.74	5.18	6.42	4.45	4.98	4.30	4.18	4.56	5.43
5	5.32	6.21	3.95	4.77	5.15	5.78	4.46	4.03	4.29	4.35	4.59	5.27
6	5.15	6.15	4.73	4.67	4.95	5.43	4.45	4.33	4.20	4.34	4.56	5.15
7	5.50	6.13	4.85	4.77	4.80	5.01	4.40	4.20	4.18	4.40	4.57	5.16
8	4.95	6.13	4.87	5.31	4.76	4.79	4.32	4.17	4.19	4.36	4.60	5.20
9	5.70	6.13	5.23	5.20	4.68	4.64	4.35	4.15	4.23	4.34	4.62	5.29
10	5.23	6.13	5.15	5.14	4.63	4.55	4.23	4.25	4.17	4.40	4.62	5.44
11	5.32	6.10	4.89	5.50	4.64	4.59	4.24	4.44	4.16	4.42	4.64	5.56
12	5.83	6.20	4.87	4.95	4.69	4.56	4.24	4.38	4.11	4.40	4.65	5.60
13	6.50	6.26	4.73	4.86	4.65	4.70	4.21	4.17	4.10	4.42	4.68	5.71
14	6.50	6.30	3.10	4.90	4.62	4.75	4.36	4.21	4.07	4.42	4.72	5.66
15	6.10	6.35	3.15	4.78	4.56	4.69	4.45	4.53	4.10	4.45	4.76	5.63
16	6.35	6.42	3.18	4.80	4.57	4.55	4.37	4.53	4.09	4.50	4.80	5.66
17	6.55	6.48	3.75	5.94	4.60	4.69	4.30	4.34	4.20	4.44	4.84	5.37
18	7.01	6.32	4.73	4.95	4.62	5.04	4.25	4.34	4.25	4.41	4.75	5.36
19	6.85	6.39	5.85	4.86	4.65	5.04	4.22	4.30	4.26	4.42	4.65	5.25
20	6.63	6.63	5.33	4.82	4.64	4.74	4.21	4.32	4.27	4.44	4.58	5.12
21	6.53	6.65	4.75	4.66	4.58	4.63	4.13	4.30	4.55	4.43	4.55	5.04
22	7.00	6.98	4.78	4.67	4.62	4.45	4.10	4.25	4.89	4.45	4.57	4.98
23	6.81	7.15	4.63	4.69	4.63	4.61	4.11	4.41	4.78	4.47	4.50	4.98
24	6.76	7.10	4.65	4.69	4.59	4.56	4.15	4.52	5.04	4.48	3.68	4.81
25	6.64	7.30	4.62	4.65	4.63	4.36	4.17	4.58	5.26	4.50	3.32	4.65
26	6.59	7.33	4.66	4.63	4.54	4.37	4.19	4.48	4.55	4.50	3.45	4.50
27	6.35	7.45	4.65	4.62	4.54	4.36	4.22	4.33	4.44	4.48	3.63	4.45
28	6.23	8.68	4.65	4.64	4.53	4.46	4.03	4.43	4.36	4.43	4.21	4.49
29	6.22	.....	4.78	4.72	4.46	4.45	4.02	4.41	4.31	4.40	4.64	.....
30	6.15	.....	4.76	4.66	4.82	4.49	4.00	4.35	4.35	4.44	4.84	.....
31	6.10	.....	4.79	.....	4.88	.....	3.96	4.47	.....	4.47	.....	.....
1896.												
1	4.15	6.33	4.68	4.75	5.30	4.55	3.98	4.17	3.71	4.10	4.47	.....
2	4.16	6.47	4.55	4.88	5.11	4.72	3.94	4.21	3.76	4.09	4.31	.....
3	4.81	6.36	3.73	4.75	4.62	4.73	4.01	4.22	3.92	4.05	4.19	.....
4	5.18	6.37	3.45	4.65	5.00	4.75	3.99	4.22	3.92	4.05	4.02	.....
5	5.35	6.45	3.68	4.72	4.79	4.90	3.94	4.13	3.92	4.03	3.99	.....
6	5.51	6.35	4.12	4.69	4.83	9.40	3.92	4.08	3.86	4.05	4.01	.....
7	5.72	6.44	4.82	4.72	4.68	6.48	3.89	4.42	3.82	4.08	3.93	.....
8	5.90	6.44	5.10	4.75	4.58	4.98	3.92	4.24	3.78	4.13	3.98	.....
9	6.01	6.12	5.06	4.80	4.55	4.21	4.00	3.95	3.79	4.16	3.78	.....
10	6.20	6.23	5.27	4.82	4.57	3.98	3.95	3.96	3.85	4.15	4.80	.....
11	6.22	5.66	5.08	4.81	4.62	3.56	4.35	3.95	3.91	4.22	4.90	.....
12	6.38	5.64	5.02	5.18	4.52	3.63	4.21	3.85	4.04	4.27	4.82	.....
13	6.52	5.65	4.68	5.91	4.56	3.58	4.12	3.87	4.10	4.27	4.73	.....
14	6.68	5.54	4.35	5.60	4.63	3.59	4.08	3.89	4.18	4.26	3.79	.....
15	6.60	5.34	3.59	5.25	4.53	3.61	3.93	3.86	4.23	4.28	4.25	6.18
16	6.48	5.66	3.80	4.94	4.68	3.65	3.86	3.84	4.24	4.24	4.11	.....
17	6.45	5.65	3.35	5.09	4.69	3.62	3.85	3.80	4.20	4.20	4.12	5.85
18	6.57	5.66	4.65	5.25	4.65	3.56	3.86	3.84	4.15	4.20	3.95	.....
19	6.68	5.63	4.99	4.93	4.63	3.55	3.90	3.84	4.10	4.19	3.75	5.41
20	6.43	5.53	5.16	5.64	4.63	3.76	3.91	3.86	4.13	4.18	3.65	.....
21	6.30	5.44	5.17	5.42	4.61	3.96	3.93	3.88	4.16	4.27	3.45	.....
22	6.19	5.42	4.76	5.14	4.54	4.14	3.93	3.86	4.17	4.32	3.88	5.67
23	6.08	5.50	4.95	5.37	4.52	4.29	3.94	3.91	4.21	4.32	5.25	.....
24	6.46	5.28	5.02	5.38	4.45	4.12	3.94	3.91	4.15	4.35	5.05	.....
25	6.64	4.96	4.75	4.75	4.41	4.43	3.99	3.87	4.09	4.32	5.49	5.56
26	6.46	4.95	4.65	4.72	4.39	4.56	4.03	3.82	4.07	4.33	6.54	.....
27	6.43	4.93	4.74	4.72	4.52	4.03	4.12	3.77	4.10	4.35	5.46	.....
28	6.25	4.93	4.71	5.46	4.53	3.93	4.13	3.76	4.10	4.28	4.98	5.42
29	6.08	4.90	4.72	4.90	4.62	3.92	4.13	3.77	4.05	4.35	.....	.....
30	6.25	.....	4.75	4.23	4.63	3.90	4.12	3.75	4.05	4.56	.....	.....
31	6.24	.....	4.76	.....	4.52	.....	4.13	3.72	.....	4.57	.....	.....
1897.												
1	5.24	.....	.....	.....	4.46	4.52	7.71	3.89	4.24	4.16	.....	.....
2	.....	.....	7.53	.....	4.44	4.44	5.32	3.85	4.20	4.16	.....	.....
3	.....	.....	.....	5.83	4.52	4.41	4.69	3.81	4.15	4.17	.....	.....
4	.....	.....	.....	.....	4.54	4.80	4.60	3.79	4.15	4.16	.....	.....
5	4.96	.....	7.59	.....	4.56	4.64	4.48	4.02	4.13	4.16	.....	.....

Mean daily gage height, in feet, of Loup River at Columbus, 1894–1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1897.												
6					4.57	4.78	4.22	4.42	4.09	4.16		
7					4.57	4.70	4.02	4.31	4.12	4.17		
8	5.18			4.88	4.60	4.68	3.84	4.39	4.03	4.18		
9			7.68	4.77	4.62	4.68	3.78	4.71	4.07	4.16		
10				4.70	4.69	4.68	3.86	4.70	4.22	4.18		
11				4.56	4.63	4.63	3.92	4.81	4.31	4.29		
12	7.18		8.45	4.44	4.66	4.70	4.02	4.61	4.36	4.43		
13				4.84	4.63	4.77	3.96	4.54	4.36	4.46		
14				4.93	4.63	4.75	3.91	4.48	4.34	4.44		
15	7.04			4.74	4.66	4.76	4.20	4.40	4.34	4.44		
16			5.73	4.70	4.67	4.74	4.08	4.33	4.30	4.50		
17				4.77	4.66	4.72	3.92	4.28	4.37	4.58		
18				4.91	4.65	4.69	3.84	4.19	4.28	5.00		
19			5.43	4.53	4.66	4.82	3.78	4.17	4.25	5.02		
20		6.45		4.63	4.62	4.74	3.95	4.15	4.23	4.86		
21				4.61	4.64	4.54	4.00	4.15	4.20	4.82		
22				4.62	4.77	4.43	3.96	4.15	4.20	4.76		
23		6.45	4.85	4.86	4.78	4.35	3.95	4.15	4.21	4.72		
24				4.82	4.82	4.34	3.96	4.16	4.24	4.80		
25				4.72	4.77	4.34	3.95	4.15	4.26	4.68		
26		7.68	4.59	4.66	4.66	4.44	3.98	4.20	4.26	4.64		
27				4.54	4.60	4.70	3.93	4.15	4.22	4.81		
28				4.41	4.68	4.95	3.85	4.10	4.20	6.26		
29				4.40	4.62	4.79	3.85	4.20	4.18	4.80		
30			4.76	4.54	4.55	5.00	3.86	4.23	4.16	4.75		
31					4.47		3.93	4.28				
1898.												
1				4.51	4.78	5.00	4.64	4.20	4.37	4.56	4.90	
2				4.77	4.77	4.95	4.64	4.24	4.34	4.58	4.85	
3				4.75	4.86	5.02	4.60	4.28	4.30	4.59	4.80	
4				4.77	5.07	5.14	4.62	4.63	4.31	4.66	4.75	
5				4.79	5.33	5.66	4.83	4.95	4.30	4.63	4.75	
6				4.82	5.28	5.95	4.88	5.24	4.30	4.64	4.80	
7				4.86	5.26	5.68	4.83	5.16	4.30	4.67	4.80	
8				4.81	5.22	5.63	4.83	4.97	4.32	4.67	4.85	
9				4.76	5.18	5.56	4.74	4.85	4.31	4.72	4.90	
10				4.80	5.16	5.46	4.66	4.77	4.36	4.74	4.90	
11				4.79	5.19	5.35	4.68	4.68	4.42	4.84	4.94	
12				4.86	5.19	5.26	4.65	4.64	4.48	4.97	4.90	
13				4.83	5.16	5.32	4.63	4.61	4.82	4.90		
14				5.06	5.07	5.36	4.67	4.58	5.03	4.82		
15				5.02	4.91	5.42	4.66	4.57	4.93	4.78		
16				4.93	4.95	5.36	4.65	4.59	4.89	4.76		
17				4.83	4.96	5.35	4.62	4.67	4.85	4.76		
18				4.77	5.15	5.30	4.54	4.83	4.81	4.77		
19				4.86	5.19	5.30	4.49	4.78	4.80	4.86		
20				4.93	5.18	5.33	4.44	4.66	4.73	4.92		
21				4.87	5.41	5.40	4.43	4.63	4.65	4.86		
22				4.75	5.44	5.50	4.41	4.65	4.49	4.82		
23				4.71	5.48	5.39	4.45	4.63	4.41	4.80		
24				4.73	5.68	5.00	4.35	4.62	4.50	4.85		
25				4.77	5.40	4.77	4.31	4.62	4.57	4.90		
26				4.85	5.64	4.71	4.30	4.63	4.58	4.80		
27				4.83	5.46	4.68	4.30	4.63	4.57	4.90		
28				4.83	5.34	4.67	4.28	4.56	4.56	4.90		
29				4.87	5.11	4.65	4.26	4.45	4.56	4.85		
30				4.81	5.10	4.66	4.26	4.41	4.56	4.80		
31					4.98		4.22	4.39		4.95		
1899.												
1					5.30		5.50	4.30	4.80	4.40		
2				5.40	4.95	5.00		4.25	4.85	4.40		
3				5.60	4.60		5.90	4.20	4.80	4.40		
4				5.80	4.70	4.80		4.25	4.80	4.40		
5				5.70	4.90		5.70	4.55	4.70	4.45		
6				5.00	4.95	5.40		4.93	4.60	4.40		
7				4.90	5.05		5.60	4.90	4.55	4.40		
8				5.00	4.95			4.80	4.50	4.40		
9				4.95	5.15			4.85	4.80	4.40		
10				4.90	5.00		4.40	4.80	4.70	4.40		

Mean daily gage height, in feet, of Loup River at Columbus, 1894–1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1899.												
11				5.00	4.95	5.40		4.70	4.60	4.40		
12				4.90	4.80		4.00	4.85	4.50	4.40		
13				4.80	4.85		4.20	4.20	4.45	4.40		
14				4.90	4.97		4.21	4.10	4.40	4.50		
15				5.10	5.30		4.20	4.50	4.40	4.80		
16				5.20	5.15	4.80	4.10	4.20	4.40	4.70		
17				5.15	5.14		4.20	4.40	4.40	4.75		
18				5.10	4.95	4.70	4.15	4.40	4.40	4.70		
19				5.00	5.00		4.00	4.50	4.40	4.60		
20				4.90	5.05		3.98	4.61	4.40	4.50		
21				4.90	5.40	4.95	4.00	4.80	4.40	4.50		
22				4.90	5.80		4.10	4.70	4.40	4.70		
23				5.00	5.54		4.25	4.75	4.40	4.60		
24				4.90	5.40	5.10	4.20	4.80	4.40	4.60		
25				4.85			4.21	4.81	4.40	4.55		
26				4.90			4.20	4.80	4.40	4.55		
27				5.00		5.90	4.20	4.81	4.40	4.50		
28				5.40			4.22	4.80	4.40	4.55		
29				5.60	5.40	5.80	4.23	4.70	4.40	4.60		
30				5.80			4.50	4.60	4.40	4.65		
31							4.40	4.70		4.65		
1900.												
1				4.75	5.10	4.85	3.78	4.43	4.15	4.45	4.70	
2				4.75	5.00	4.70	3.90	4.43	4.20	4.45	4.65	
3				4.75	4.95	4.50	3.87	4.32	4.23	4.48	4.60	
4				4.75	4.96	4.85	4.54	4.28	4.23	4.48	4.48	
5				4.75	4.98	4.87	4.28	4.25	4.25	4.50	4.48	
6				4.75	4.95	4.82	4.93	4.25	4.25	4.50	4.45	
7				4.75	4.98	4.75	4.46	3.98	4.25	4.55	4.40	
8				4.71	5.32	4.65	4.62	4.05	4.27	4.55	4.43	
9				4.70	5.30	4.55	4.70	4.63	4.27	4.58	4.45	
10				4.72	5.00	4.53	4.40	4.68	4.28	4.60	4.48	
11				4.74	4.95	4.65	4.35	4.55	5.98	4.58	4.55	
12				4.70	4.95	4.65	4.20	4.44	5.25	4.58	4.55	
13				4.80	5.68	4.62	4.15	4.48	5.45	4.58	4.59	
14				4.81	5.20	4.61	3.98	4.43	5.63	4.58	4.55	
15				4.80	5.14	4.65	3.93	4.63	5.48	4.57	4.55	
16				4.82	5.05	4.65	4.28	5.53	5.00	4.57	4.50	
17				4.85	5.03	6.28	4.73	5.83	4.70	4.56	4.58	
18				4.87	5.01	5.20	4.78	5.50	4.48	4.55		
19				4.90	5.00	4.85	4.55	5.38	4.48	4.60		
20				5.00	4.95	3.98	4.38	4.48	4.45	4.66		
21				5.30	4.75	3.95	4.35	4.42	4.48			
22				5.30	4.72	4.10	4.43	4.38	4.48			
23				5.30	4.71	3.85	4.45	4.32	4.50			
24				5.32	4.70	3.87	4.98	4.35	4.48			
25				5.27	4.60	3.83	5.05	4.50	4.48			
26				5.26	4.65	3.88	5.00	4.57	4.48			
27				5.25	4.90	3.85	4.40	4.70	4.50			
28				5.25	4.80	3.83	4.50	4.68	4.48	5.00		
29				5.20	4.82	3.83	4.38	4.53	4.48	5.00		
30				5.20	4.70	3.80	4.35	4.35	4.40	4.81		
31					6.65		4.35	4.28		4.76		
1901.												
1				4.50	4.70	4.60	5.05	4.15	4.50	4.60	4.90	
2				4.48	4.70	4.60	5.00	4.10	4.50	4.65	5.10	
3				4.50	4.70	4.60	4.90	4.10	4.50	4.65	5.30	
4				4.60	4.70	4.70	4.90	4.10	4.57	4.65	5.20	
5				4.70	4.70	4.80	4.90	4.10	4.70	4.65	5.10	
6				4.80	4.80	4.70	4.70	4.13	4.80	4.65	5.00	
7				4.55	4.80	4.70	4.45	4.12	4.90	4.65	4.90	
8				4.50	4.85	4.70	4.38	4.12	4.95	4.65	4.80	
9				4.50	4.90	4.70	4.30	4.10	4.95	4.70	4.60	
10				4.60	4.90	4.70	4.20	4.10	5.10	4.80	4.55	
11				4.70	4.80	4.60	4.10	4.52	5.10	4.80	4.55	
12				4.80	4.80	4.60	4.10	4.40	5.45	4.80	4.55	
13				5.00	4.80	4.60	4.10	4.30	5.55	4.80	4.55	
14				5.10	4.70	4.60	3.97	4.45	5.60	4.80	4.60	
15				5.20	4.70	4.60	3.95	4.40	5.60	4.80	4.60	

Mean daily gage height, in feet, of Loup River at Columbus, 1894–1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1901.												
16				5.30	4.70	6.45	4.00	4.40	5.60	4.75	4.55	
17				5.20	4.60	6.45	4.00	4.40	5.40	4.70	4.55	
18				5.00	4.60	5.80	4.00	4.35	5.30	4.70	4.55	
19				5.00	4.60	5.90	4.00	4.30	5.10	4.65	4.55	
20				5.00	4.65	6.00	4.05	4.27	4.70	4.65	4.55	
21				4.85	4.70	6.10	4.40	4.27	4.70	4.65	4.55	
22				4.85	4.80	6.05	4.30	4.27	4.70	4.65	4.55	
23				4.80	4.75	6.00	4.20	4.30	4.70	4.65	4.55	
24			4.60	4.80	4.80	5.90	4.10	4.40	4.70	4.65	4.55	
25			4.60	4.70	4.85	5.70	4.00	4.70	4.60	4.70	4.55	
26			4.60	4.90	4.90	5.60	3.90	4.55	4.50	4.70	4.55	
27			4.50	4.70	4.90	5.45	3.85	4.50	4.50	4.70	4.55	
28			4.50	4.90	4.80	5.34	4.00	4.45	4.50	4.70	4.60	
29			4.50	4.90	4.80	5.15	3.95	4.45	4.50	4.70	4.60	
30			4.45	4.80	4.70	5.10	4.10	4.45	4.55	4.75	4.65	
31			4.50		4.60		4.20	4.45		4.90		
1902.												
1				4.65	4.80	4.85	6.00	4.80	5.40	5.00	4.79	
2				4.60	4.80	4.95	6.60	4.70	5.10	5.00	4.80	
3				4.55	4.80	5.00	6.80	4.60	4.60	5.00	4.80	
4				4.50	4.85	5.40	6.10	4.60	4.55	5.00	4.85	
5				4.60	4.90	5.80	6.10	4.55	4.50	4.92	4.85	
6				4.80	5.00	5.90	6.05	4.50	4.50	4.95	4.85	
7				4.70	5.10	5.95	6.10	4.45	4.50	4.95	4.90	
8			5.79	4.70	5.00	5.00	6.00	4.40	4.45	4.90	4.95	
9			5.79	4.70	4.95	4.90	5.90	5.00	4.45	4.80	4.95	
10			5.00	4.70	4.90	4.85	6.45	6.10	4.45	4.80	4.95	
11			4.70	4.70	4.80	4.70	5.59	4.90	4.48	5.00	4.80	
12			4.60	4.73	4.80	4.65	5.25	4.70	4.45	5.60	4.70	
13			4.70	4.76	4.90	4.65	5.00	4.65	4.40	5.50	4.65	
14			4.80	4.75	5.10	4.60	5.50	4.62	4.40	5.40	4.65	
15			4.80	4.75	5.30	4.60	5.25	4.60	4.35	5.30	4.65	
16			4.80	4.70	5.30	4.70	5.10	4.60	4.30	5.20	4.60	
17			4.70	4.70	5.30	4.65	5.05	4.60	4.20	5.10	4.65	
18			4.70	4.70	5.70	4.65	5.10	5.00	4.40	5.00	4.70	
19			4.60	4.70	5.90	5.00	5.10	5.55	4.50	4.90	4.75	
20			4.60	4.70	6.10	5.40	5.00	5.50	4.65	4.90	4.80	
21			4.64	4.70	5.56	5.00	4.90	5.50	4.80	4.90	4.80	
22			4.65	4.75	5.55	4.95	4.80	5.40	5.80	4.90	4.80	
23			4.68	4.80	5.50	4.70	4.75	5.40	6.10	4.90	4.81	
24			4.70	4.80	5.40	4.80	4.70	5.30	5.10	4.90	4.85	
25			4.80	4.80	5.36	4.70	4.80	5.50	5.10	4.90	4.85	
26			4.90	4.85	5.15	4.60	4.85	5.55	5.10	4.90	4.85	
27			4.95	5.15	5.00	4.80	4.80	5.45	5.40	4.90	4.85	
28			4.97	5.10	4.95	4.80	4.85	5.50	5.20	4.85	4.85	
29			5.00	5.00	4.90	5.00	4.85	5.59	5.10	4.85	4.85	
30			4.80	4.90	4.85	5.00	4.85	5.80	5.05	4.80		
31			4.70		4.85		4.80	5.95		4.80		
1903.												
1				5.00	5.20	5.80	5.00	6.72	4.90	4.40	4.60	4.95
2				4.90	5.20	5.60	4.80	6.60	4.80	4.45	4.60	4.95
3				5.10	5.20	5.50	4.90	5.60	4.70	4.45	4.70	5.00
4				5.00	5.20	5.45	7.00	5.30	4.60	4.50	4.70	5.00
5				5.00	5.10	5.40	6.60	5.00	4.50	4.50	4.70	4.95
6				4.95	5.10	5.30	5.65	4.90	4.50	4.55	4.70	
7				5.00	5.10	5.30	5.00	4.80	4.90	4.55	4.70	
8				5.00	5.15	5.30	4.95	4.70	4.80	4.55	4.70	
9				5.10	5.15	5.30	4.70	4.70	4.70	4.50	4.70	
10				5.20	5.15	5.25	4.70	4.70	4.70	4.50	4.65	
11				5.20	5.40	5.12	4.70	4.90	4.75	4.60	4.65	
12				5.10	5.90	5.00	4.50	5.10	4.75	4.60	4.65	
13			5.45	5.00	5.75	4.95	4.50	5.60	4.75	4.75	4.65	
14			5.35	5.20	5.50	4.85	4.55	6.40	4.90	4.95	4.70	
15			5.20	5.25	5.25	4.85	5.55	6.00	4.80	4.90	4.70	
16			5.20	5.10	5.25	4.85	5.95	5.10	4.70	4.80	4.80	
17			5.25	5.10	5.25	4.85	5.56	5.15	4.60	4.80	5.00	
18			5.22	5.20	5.10	4.75	5.25	5.00	4.50	4.70	5.20	
19			5.25	5.20	5.10	4.70	5.10	4.90	4.53	4.75	5.30	
20			5.10	5.30	4.95	4.70	5.05	4.70	4.50	4.75	5.30	

Mean daily gage height, in feet, of Loup River at Columbus, 1894–1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1903.												
21			4.90	5.30	5.00	4.70	4.90	4.60	4.50	4.70	5.40	.....
22			4.78	5.20	5.10	4.80	4.80	4.50	4.40	4.70	5.45	.....
23			4.80	5.10	5.15	4.80	4.70	4.50	4.40	4.70	5.45	.....
24			4.90	5.20	5.55	4.80	4.60	4.50	4.40	4.68	5.40	.....
25			4.80	5.10	5.40	4.95	4.60	4.60	4.40	4.65	5.50	.....
26			4.80	5.05	5.35	5.00	4.60	4.80	4.40	4.65	5.15	.....
27			4.80	5.00	5.15	5.05	4.60	7.20	4.40	4.63	5.00	.....
28			4.85	5.00	5.40	5.05	4.60	6.80	4.40	4.62	4.90	.....
29			5.12	5.00	5.65	5.00	4.70	5.80	4.40	4.65	4.60	.....
30			5.15	5.00	5.70	4.95	5.60	5.50	4.40	4.61	4.70	.....
31			5.20	.....	5.80	.....	5.40	5.00	.....	4.60	.....	.....
1904.												
1			.....	4.95	4.95	4.70	4.90	4.52	4.90	5.10	4.45	.....
2			.....	4.90	4.90	4.80	4.90	4.48	5.00	5.35	4.45	.....
3			.....	4.92	4.90	5.10	4.90	4.71	5.60	5.30	4.40	.....
4			.....	4.90	4.95	5.15	4.95	4.84	5.20	5.25	4.45	.....
5			.....	4.90	4.95	5.20	5.00	4.87	5.00	5.10	4.45	.....
6			.....	4.95	4 98	5.15	5.78	4.85	4.65	4.85	4.30	.....
7			.....	5.00	.....	4.95	6.00	4.80	4.65	4.65	4.45	.....
8			.....	5.20	5.30	4.95	6.25	4.85	4.65	4.65	4.55	.....
9			.....	5.10	5.30	5.10	5.80	5.15	4.56	4.70	4.55	.....
10			.....	5.05	5.25	7.30	6.49	5.15	4.48	4.95	4.60	.....
11			.....	5.00	5.20	5.60	6.20	4.75	4.40	4.85	4.60	.....
12			.....	5.00	5.15	5.40	5.42	4.65	4.50	5.00	4.60	.....
13			5.35	4.95	5.15	5.30	4.96	4.55	4.50	4.90	4.60	.....
14			5.35	4.90	5.15	5.80	4.82	4.50	4.50	4.80	4.55	.....
15			5.30	4.90	5.15	5.40	4.72	4.42	5.10	4.80	4.60	.....
16			5.10	4.90	5.05	5.20	4.60	4.45	4.60	4.75	4.60	.....
17			5.00	4.90	5.00	5.00	4.75	4.50	4.55	4.70	4.60	.....
18			4.95	4.95	5.00	4.85	6.30	4.60	4.45	5.10	4.65	.....
19			4.90	4.95	5.00	4.90	5.11	4.72	4.55	6.30	4.60	.....
20			4.85	5.00	5.00	4.80	5.10	4.77	4.50	6.10	4.69	.....
21			4.80	5.05	5.00	4.90	5.10	4.85	4.60	5.00	4.65	.....
22			4.80	5.05	5.00	4.75	5.80	4.65	4.70	4.80	4.65	.....
23			4.80	5.10	4.98	4.60	4.80	4.45	4.70	4.80	4.65	.....
24			4.80	5.15	5.00	4.75	4.70	4.40	4.60	4.55	4.80	.....
25			4.75	5.40	.....	5.42	4.70	4.40	4.70	4.50	4.50	.....
26			4.75	5.35	5.90	5.45	4.75	4.40	4.70	4.40	4.50	.....
27			4.75	5.20	5.00	5.30	4.70	4.40	4.70	4.45	.....	.....
28			4.80	5.05	4.90	5.10	4.95	4.40	4.90	4.40	.....	.....
29			4.80	4.98	4.50	5.00	4.70	4.40	5.00	4.45	.....	.....
30			4.89	4.95	4.50	4.92	4.64	4.45	5.00	4.50	.....	.....
31			4.95	.....	4.50	.....	4.56	5.10	.....	4.45	.....	.....
1905.												
1			.....	4.3	4.6	5.2	6.85	4.8	4.4	4.25	4.2	.....
2			.....	4.4	4.55	5.0	6.25	6.8	4.35	4.4	4.15	.....
3			.....	4.5	4.7	5.5	6.7	5.9	4.3	4.35	4.1	.....
4			.....	4.9	4.6	5.0	6.55	5.0	4.3	4.3	4.1	.....
5			.....	4.6	4.75	4.7	5.85	4.75	4.5	4.2	4.25	.....
6			.....	4.4	4.85	4.65	5.7	4.4	4.6	4.2	4.5	.....
7			.....	4.2	4.8	4.35	5.8	4.45	4.85	4.2	4.35	.....
8			.....	4.1	4.7	4.25	5.4	4.5	4.85	4.2	4.3	4.5
9			.....	4.2	4.75	4.45	5.22	4.4	4.55	4.3	4.3	5.7
10			.....	4.3	5.6	4.35	5.0	4.35	4.5	4.3	4.35	5.7
11			.....	4.3	5.0	4.6	4.95	4.35	4.45	4.3	4.35	5.75
12			.....	4.2	4.9	4.6	4.9	4.3	4.4	4.3	4.4	5.7
13			.....	4.2	5.8	4.55	4.75	4.3	4.45	4.35	4.4	5.8
14			.....	4.3	6.35	4.45	4.5	4.25	4.95	4.4	4.45	6.5
15			.....	4.4	6.9	4.5	5.0	4.3	5.5	4.4	4.35	6.0
16			.....	4.3	5.8	4.6	4.95	4.55	5.1	4.6	4.35	5.95
17			4.4	4.3	5.4	4.7	4.85	4.45	4.95	4.5	4.35	5.85
18			4.6	4.3	5.0	4.6	4.8	4.6	5.25	4.45	4.45	.....
19			4.7	4.2	4.95	4.6	4.8	5.5	6.25	4.55	4.4	.....
20			4.9	5.6	4.9	4.7	4.8	4.5	5.3	4.45	4.4	.....
21			4.7	5.2	4.9	4.85	4.85	4.5	4.85	4.3	4.35	.....
22			4.7	5.15	4.8	5.0	4.85	4.85	4.65	4.4	4.3	.....
23			4.6	5.1	4.75	6.4	4.95	4.55	4.4	4.35	4.65	.....
24			4.4	5.05	4.65	6.5	5.15	4.6	4.3	4.2	4.55	.....
25			4.5	5.0	4.6	5.65	4.95	4.7	4.45	4.2	4.65	.....

Mean daily gage height, in feet, of Loup River at Columbus, 1894–1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905.												
26			4.5	4.95	4.9	5.2	7.95	4.55	4.1	4.2	4.5	
27			4.6	4.95	4.95	4.95	6.4	4.55	4.3	4.2	4.6	
28			4.4	4.95	5.1	6.9	5.4	4.4	4.25	4.25	4.5	
29			4.3	4.9	6.95	7.00	5.2	4.4	4.25	4.35	3.95	
30			4.2	4.7	6.1	6.05	4.95	4.4	4.25	4.25	5.45	
31			4.3		5.75		4.5	4.4		4.25		
1906.												
1					8.40	4.60	5.40	4.80	4.25	4.40	4.60	
2					6.55	4.40	4.75	4.70	4.30	4.35	4.65	
3					5.75	4.50	4.65	4.50	4.45	4.35	4.80	
4					5.75	4.50	4.35	4.85	4.40	4.40	4.90	
5					5.50	4.45	4.30	5.00	4.40	4.30	4.95	
6					5.00	4.50	4.25	4.90	4.40	4.30	4.95	
7					5.00	4.50	4.20	6.10	4.35	4.30	4.90	
8				4.75	4.90	4.40	4.20	5.70	4.35	4.25	4.70	
9				4.90	4.70	4.40	4.20	5.35	4.30	4.25	4.65	
10				4.80	4.30	4.35	4.15	5.30	4.10	4.25	4.75	
11				4.65	4.30	4.25	4.15	4.70	4.20	4.35	4.55	
12				4.55	4.20	4.20	4.10	4.55	4.30	4.35	4.35	
13				4.80	4.35	4.20	4.20	4.60	4.55	4.35	4.50	
14				5.40	4.30	4.25	4.40	4.60	5.50	4.40	4.45	
15				5.75	4.30	4.35	4.20	4.40	4.95	4.30	4.50	
16				4.90	4.30	4.35	4.25	4.35	4.75	4.50	4.50	
17				5.00	4.30	4.30	4.20	4.30	5.15	4.40	4.45	
18				4.95	4.20	4.35	4.25	4.25	4.80	4.50	4.55	
19				5.50	4.20	4.40	4.65	4.20	4.65	4.50	4.50	
20				5.50	4.20	4.30	4.45	4.15	4.40	4.60	4.50	
21				4.90	4.20	4.25	4.65	4.15	4.50	4.65		
22				4.85	4.30	4.25	4.40	4.05	4.45	5.05		
23				4.80	4.50	4.15	4.45	4.05	4.45	5.05		
24				4.80	4.55	4.25	4.45	4.05	4.50	5.30	4.70	
25				4.75	5.10	4.40	4.35	4.10	4.50	5.00	4.70	
26				4.80	4.75		4.25	4.40	4.50	4.75	4.75	
27				5.65	4.85	4.85	4.65	4.65	4.45	4.60	4.80	
28				6.10	4.90	4.80	4.25	4.65	4.40	4.95	4.80	
29				5.75	4.65	4.85	4.55	4.35	4.40	4.55	4.80	
30				6.85	5.30	4.60	4.60	4.30	4.45	4.85	4.75	
31					4.80		4.55	4.30		4.75		

Estimated monthly discharge of Loup River at Columbus, 1895–1906.

[Drainage area, 13,540 square miles.]

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
March.								
1902[a]	6,830	2,500	3,343	159,200				1.51
1903[b]	8,250	4,090	5,554	209,300				.72
1904[b]	5,400	3,130	3,715	140,000				.22
1905[c]	6,950	3,500	5,017	149,300				.93
April.								
1895	3,680	2,300	2,754	168,900	0.217	0.24	12	2.06
1896	7,020	1,970	4,081	242,800	.301	.35	6	4.84
1897	7,120	2,680	3,695	219,900	.273	.30	8	3.88
1898	3,520	2,130	2,794	166,300	.206	.23	14	1.66
1899	5,530	2,340	3,280	195,400	.242	.27	28	.98
1900	4,740	2,380	3,352	199,500	.248	.28	6	4.47
1901	4,680	2,570	3,254	193,600	.240	.27	14	1.92
1902	3,210	1,980	2,409	143,400	.178	.20	14	1.42
1903	4,740	3,400	4,027	239,600	.297	.33	21	1.56
1904	4,300	2,740	3,343	198,900	.247	.27	17	1.57
1905	11,100	3,050	5,492	326,800	.406	.45	11	4.15
1906	16,100	2,500	5,580	332,000	.413	.46	8	5.47

[a] 24 days. [b] March 13 to 31. [c] March 17 to 31.

Estimated monthly discharge of Loup River at Columbus, 1895–1906—Continued.

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
May.								
1895	4,420	2,600	2,966	182,400	0.219	0.25	10	2.48
1896	4,810	2,310	2,985	183,500	.221	.25	10	2.54
1897	2,880	1,850	2,496	153,500	.184	.21	17	1.26
1898	5,100	2,420	3,509	215,800	.259	.30	6	5.04
1899	4,870	1,910	3,035	186,600	.224	.25	9	2.91
1900	10,550	2,380	3,717	228,500	.274	.31	12	2.57
1901	2,740	1,850	2,346	144,200	.173	.20	12	1.61
1902	7,440	2,200	3,226	198,300	.238	.28	7	4.27
1903	6,500	2,870	4,085	251,200	.301	.34	6	5.46
1904	.6,500	1,930	2,972	183,000	.219	.25	6	4.10
1905	19,680	5,150	8,665	522,800	.640	.74	11	6.54
1906	25,000	1,600	4,590	282,000	.340	.39	13	2.89
June.								
1895	9,080	2,340	3,591	213,700	.265	.30	6	4.76
1896	8,000	1,930	3,009	179,000	.228	.25	5	4.94
1897	9,550	1,800	2,891	172,000	.213	.24	5	4.11
1898	6,680	2,000	4,022	239,300	.297	.33	14	2.34
1899	7,710	1,800	3,893	231,600	.288	.33	8	3.92
1900	14,300	2,080	3,493	207,800	.258	.29	13	2.30
1901	7,100	1,720	3,467	206,300	.256	.29	6	4.92
1902	5,940	2,210	3,250	193,300	.240	.27	6	4.45
1903	6,060	2,150	3,188	189,700	.235	.26	16	1.68
1904	20,000	2,150	4,364	259,700	.322	.36	6	5.53
1905	20,000	3,720	8,117	483,000	.599	.67	11	6.07
1906	4,800	1,900	2,890	172,000	.214	.24	12	2.06
July.								
1895	2,850	1,450	2,122	130,500	.157	.18	18	.98
1896	3,670	2,310	2,712	166,700	.200	.23	6	4.12
1897	11,820	1,600	2,616	155,700	.193	.21	8	2.53
1898	2,530	1,620	1,946	119,700	.140	.16	6	2.88
1899	6,980	1,000	2,104	125,200	.155	.18	8	2.47
1900	5,380	1,980	3,265	200,800	.240	.28	5	5.55
1901	3,050	1,000	1,615	96,100	.112	.13	22	.90
1902	10,900	3,390	5,669	348,500	.420	.48	8	6.29
1903	15,750	2,040	3,549	211,200	.262	.29	4	6.88
1904	11,750	2,150	4,266	262,300	.314	.36	6	6.13
1905	25,800	2,900	9,067	557,500	.670	.77	17	4.58
1906	7,900	1,700	2,780	171,000	.206	.24	9	2.74
August.								
1895	4,100	1,520	2,289	140,700	.169	.20	8	2.49
1896	3,810	2,110	2,629	161,600	.197	.23	25	.89
1897	3,280	1,100	1,812	111,400	.134	.15	7	2.96
1898	4,720	1,650	2,655	163,300	.196	.23	8	2.84
1899	3,260	1,280	2,357	144,900	.174	.20	7	2.93
1900	7,480	1,610	3,462	212,900	.256	.30	8	3.67
1901	2,150	1,000	1,380	84,800	.100	.12	8	1.58
1902	8,150	1,680	4,767	293,100	.352	.40	11	3.77
1903	20,000	2,260	5,373	330,400	.397	.46	9	5.81
1904	3,890	1,660	2,347	144,300	.173	.20	8	2.41
1905	19,190	5,050	6,949	427,300	.513	.59	31	1.93
1906	11,600	1,000	3,120	192,000	.230	.27	13	3.52
September.								
1895	5,000	1,670	2,427	144,400	.179	.20	11	1.81
1896	2,970	2,060	2,460	146,400	.182	.20	10	2.10
1897	1,700	1,000	1,427	84,900	.105	.12	10	1.16
1898	2,950	1,460	2,003	119,200	.148	.17	13	1.35
1899	2,940	1,850	2,142	127,500	.158	.18	26	.70
1900	7,600	2,380	3,363	200,100	.249	.28	12	2.41
1901	4,780	1,760	2,853	169,800	.211	.23	5	4.89
1902	6,910	1,690	3,218	191,500	.238	.27	8	3.44
1903	3,550	2,380	2,763	164,400	.204	.23	26	.87
1904	4,960	1,660	2,375	141,300	.175	.20	9	2.24
1905	14,600	2,400	5,637	335,400	.416	.46	12	3.81
1906	7,400	1,100	2,600	155,000	.193	.22	7	2.94
October.								
1895	2,690	1,910	2,450	150,600	.181	.21	105	.20
1896	3,610	2,240	2,732	168,000	.202	.23	16	1.40
1897	10,400	1,600	3,422	210,400	.253	.29	10	3.02
1898	2,900	2,020	2,477	152,300	.193	.21	3	.83
1899	2,520	1,320	1,914	117,700	.141	.16	55	.29
1900	3,700	2,900	3,222	198,100	.238	.28	16	1.72

Estimated monthly discharge of Loup River near Columbus, 1895–1906—Continued.

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
October.								
1901	2,650	1,900	2,243	137,900	0.166	0.20	10	1.93
1902	4,710	2,500	3,011	185,100	.222	.25	13	1.95
1903	3,710	2,380	2,796	171,900	.206	.24	24	1.00
1904	9,750	1,660	2,941	180,800	.217	.25	8	3.08
1905	5,600	3,180	4,082	251,000	.301	.35	47	.74
1906	7,100	1,900	3,280	202,000	.243	.28	9	3.12
November.								
1895	3,640	2,560	3,010	179,100	.222	.25	30	.84
1898[a]	2,900	2,450	2,668	64,000				.43
1900[b]	3,150	2,300	2,679	90,000				.17
1901	3,370	1,740	2,335	138,900	.173	.19	32	.60
1902	2,870	2,040	2,501	148,800	.185	.21	87	.24
1903	5,840	2,620	3,665	218,100	.271	.30	59	.51
1904	2,500	1,510	1,961	116,600	.145	.16	229	.07
1905	5,850	2,600	4,389	261,200	.324	.36	31	1.16
1906	4,900	2,000	3,090	184,000	.229	.25	27	.93

[a] November 1 to 12, 1898. [b] November 1 to 17, 1900.

NORTH LOUP RIVER NEAR ST. PAUL.

Observations were begun at the St. Paul station on North Loup River May 4, 1895, but the records cover only the open seasons for the years 1895 to 1897, inclusive, 1899, and 1903. The station is 4 miles north of St. Paul, in sec. 22, T. 15 N., R. 10 W. The location is shown on the St. Paul topographic atlas sheet.

Discharge measurements were made from highway bridges. Refined measurements were not possible at this station on account of the shifting sandy bed and the varying angle which the thread of the current made with the bridge; neither was it practicable to obtain records of winter flow.

A different gage and a different section were used during each of the periods stated above, and the gage heights for one period are therefore not comparable with those of another. From 1895 to 1897 the gage was an inclined staff on the left bank at the lower side of an old wagon bridge. Its datum was 6.54 feet below a standard United States Geological Survey bench mark on the left bank 170 feet north of the gage. On April 18, 1899, a second inclined staff gage was installed on the left bank about 200 feet below the first one. The datum of this gage was 5.57 feet below the bench mark described above, or 0.97 foot higher than the datum of the gage used from 1895 to 1897. Between 1899 and 1903 the old wagon bridge was replaced by a steel structure one-fourth mile below, which was used for making measurements during 1903. On April 15 of that year a third gage was installed on the right bank 2 miles below the steel bridge. This gage was an inclined staff referred to one bench mark—a notch in an ash tree 30 feet south of the gage. Elevation 6.47 feet above the zero

of the gage. The gage was set to read the same as would have been recorded on the old rod of 1899 had it been in place 2 miles upstream; otherwise there is no relation between the gage heights in 1903 and those of former years.

Discharge measurements of North Loup River near St. Paul, 1895–1903.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
1895.		*Feet.*	*Sec.-ft.*	1899.		*Feet.*	*Sec.-ft.*
May 4	O. V. P. Stout	3.27	1,520	April 18	Glenn E. Smith	1.81	16,780
June 28	do	3.21	1,127	May 5	do	1.77	11,380
September 6	do	3.04	816	May 18	do	1.65	8,770
1896.				June 7	do	1.58	10,240
				June 27	do	3.90	76,900
May 9	E. M. Carbin	3.40	1,138	July 20	do	1.35	811
June 11	O. V. P. Stout	2.30	1,337	August 8	do	1.70	10,260
July 9	E. T. Youngfeldt	2.10	1,120	August 23	do	1.47	920.5
April 21	do	2.05	880	September 7	do	1.70	917
September 23	do	2.15	935	September 19	do	1.50	796
1897.				September 30	do	1.47	776
April 20	Adna Dobson	2.89	1,281	1903.			
May 11	do	2.85	1,080	April 15	J. C. Stevens	1.44	1,042
May 28	do	2.76	1,064	May 14	do	1.70	1,223
June 19	O. V. P. Stout	2.94	933	June 2	do	1.94	1,845
July 17	do	2.66	615	July 16	do	1.65	1,017
July 28	do	2.85	708	August 11	do	1.44	961
August 18	do	2.82	659	September 19	E. C. Murphy	1.49	807
October 10	Adna Dobson	2.92	819	November 28	J. C. Stevens	1.60	1,785
October 31	do	3.17	1,525				

Mean daily gage height, in feet, of North Loup River near St. Paul, 1895–1903.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1895.												
1						3.25	3.11	3.00	3.10	3.15	3.10	
2						4.00	3.09	3.05	3.10	3.15	3.37	
3						3.85	3.14	3.07	3.05	3.18	3.20	
4						3.40	3.09	3.20	2.98	3.20	3.20	
5					3.27	3.35	3.07	3.12	3.00	3.20	3.20	
6					3.26	3.22	3.05	3.10	3.00	3.25	3.17	
7					3.24	3.25	3.12	3.07	3.02	3.20	3.19	
8					3.20	3.25	3.09	3.00	3.10	3.19	3.17	
9					3.15	3.30	3.10	3.30	3.10	3.18	3.15	
10					3.20	3.25	3.10	3.25	3.07	3.20	3.12	
11					3.30	3.25	3.10	3.07	3.07	3.20	3.10	
12					3.24	3.25	3.09	3.00	3.06	3.20	3.10	
13					3.20	3.22	3.13	3.30	3.00	3.20	3.07	
14					3.20	3.23	3.14	3.15	3.00	3.21	3.02	
15					3.20	3.20	3.14	3.10	3.12	3.20	3.05	
16					3.15	3.22	3.10	3.13	3.21	3.22	3.05	
17					3.15	3.35	3.07	3.10	3.12	3.23	3.00	
18					3.16	3.30	3.05	3.02	3.14	3.20	3.02	
19					3.10	3.10	3.04	3.00	3.07	3.20	3.00	
20					3.12	3.15	3.05	2.99	3.15	3.02	3.00	
21					3.10	3.10	3.00	3.00	3.12	3.09	2.95	
22					3.05	3.10	3.05	3.00	3.90	3.10	2.66	
23					3.06	3.12	3.05	3.35	3.35	3.10	2.50	
24					3.05	3.13	3.05	3.23	3.20	3.07	2.49	
25					3.08	3.10	3.00	3.00	3.20	3.08	2.45	
26					3.05	3.12	2.99	2.98	3.19	3.08	3.70	
27					3.06	3.18	2.97	2.96	3.17	3.05	3.85	
28					3.08	3.21	2.90	3.05	3.15	3.07	3.85	
29					3.06	3.15	2.95	3.00	3.11	3.05	3.85	
30					3.40	3.17	2.95	3.25	3.10	3.07	3.85	
31					3.30		2.97	3.10		3.05		

Mean daily gage height, in feet, of North Loup River near St. Paul, 1895–1903—Con.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1896.												
1				3.38	3.52	3.57	2.10	2.20	2.04	2.18	2.19	2.70
2				3.40	3.50	3.50	2.07	2.10	2.02	2.20	2.20	.....
3				3.33	3.43	3.40	2.09	2.07	2.01	2.14	2.17	3.08
4				3.38	3.44	3.40	2.05	2.12	2.07	2.16	2.22	.....
5				3.30	3.44	3.41	2.05	2.10	2.08	2.16	2.17	3.12
6				3.35	3.40	4.65	2.04	2.08	2.10	2.15	2.15	.....
7				3.40	3.38	3.35	2.07	2.05	2.14	2.15	2.18	3.15
8				3.35	3.35	2.50	2.10	2.07	2.08	2.17	2.16	.....
9				3.32	3.40	2.30	2.45	2.11	2.04	2.17	2.20	.....
10				3.30	3.35	2.22	2.35	2.00	2.08	2.17	2.23	3.65
11				3.30	3.32	2.30	2.20	1.99	2.05	2.17	2.21	.....
12				3.80	3.34	2.25	2.12	2.05	2.12	2.20	2.20	3.72
13				3.65	3.32	2.23	2.12	2.06	2.15	2.22	2.22	.....
14				3.50	3.33	2.18	2.14	2.05	2.25	2.18	2.20	3.72
15				3.53	3.32	2.15	2.10	2.07	2.23	2.18	2.18	3.75
16				3.44	3.38	2.11	2.06	2.04	2.09	2.18	2.11	.....
17				3.50	3.42	2.10	2.05	2.05	2.12	2.15	2.20	3.82
18				4.10	3.35	2.09	2.08	2.08	2.18	2.14	2.17	.....
19				3.65	3.31	2.22	2.11	2.01	2.25	2.20	2.20	3.80
20				3.45	3.35	2.30	2.11	2.00	2.22	2.20	2.20	.....
21				3.34	3.30	2.51	2.07	2.04	2.17	2.18	2.15	3.07
22				3.34	3.32	2.80	2.05	2.07	2.11	2.15	2.30	.....
23				3.37	3.34	2.56	2.07	2.05	2.08	2.17	2.09	3.18
24				3.34	3.33	2.50	2.12	2.07	2.16	2.15	2.07	.....
25				3.32	3.32	2.53	2.05	2.04	2.15	2.11	2.11	.....
26				3.30	3.25	2.35	2.30	2.04	2.18	2.05	2.15	3.20
27				3.28	3.75	2.35	2.07	2.04	2.15	2.10	2.17	.....
28				3.40	3.27	2.28	2.15	2.07	2.15	2.17	2.14	3.20
29			3.40	3.65	3.20	2.18	2.00	2.08	2.11	2.50	2.12	.....
30			3.41	3.55	3.25	2.15	2.30	2.06	2.15	2.50	2.17	.....
31			3.40	.....	3.31	.....	2.28	2.07	.....	2.38	.....	3.75
1897.												
1				2.86	2.95	2.65	3.80	2.78	2.75	2.91	.....	.....
2	3.85	3.70	3.70	3.04	2.93	2.70	3.48	2.75	2.75	2.90	.....	.....
3				3.82	2.90	2.76	4.02	2.75	2.85	2.92	.....	.....
4	.....	3.72	3.78	3.90	2.94	2.84	3.12	2.75	2.79	2.85	.....	.....
5	3.80	.....	.....	2.80	2.92	2.82	3.13	2.81	2.80	2.85	.....	.....
6	.....	3.72	3.79	2.78	2.93	2.81	2.97	2.76	2.83	2.88	.....	.....
7			.....	2.70	2.95	2.79	2.95	3.12	2.84	2.88	.....	.....
8	4.00	3.75	.....	2.63	2.90	2.83	2.97	2.98	2.85	2.87	.....	.....
9	.....	.....	3.80	2.68	2.92	2.80	2.74	2.95	2.73	2.91	.....	.....
10	4.40	3.85	3.86	2.64	2.87	2.78	2.81	2.96	3.35	2.91	.....	.....
11	.....	.....	4.08	3.11	2.87	2.78	2.83	2.87	3.00	2.90	.....	.....
12	.....	3.88	4.22	3.12	2.85	2.77	2.81	2.84	2.97	2.88	.....	.....
13	4.70	.....	2.84	3.10	2.82	2.78	2.87	2.82	2.95	2.93	.....	.....
14	.....	3.90	2.82	3.07	2.88	2.90	2.83	2.85	2.92	2.95	.....	.....
15	4.50	.....	2.80	3.05	2.85	2.95	2.75	2.82	2.89	2.97	.....	.....
16	.....	3.92	2.83	2.96	2.85	2.95	2.67	2.82	2.89	3.04	.....	.....
17			.....	2.95	2.81	2.90	2.80	2.90	2.85	3.32	.....	.....
18	4.20	3.93	2.80	2.95	2.79	3.00	2.76	2.91	2.84	3.25	.....	.....
19			.....	3.04	2.76	2.94	2.89	2.85	2.84	3.01	.....	.....
20	.....	3.95	2.86	2.88	2.77	2.90	2.79	2.82	2.86	3.12	.....	.....
21	.....	.....	.....	2.93	2.76	3.70	2.77	2.83	2.86	3.05	.....	.....
22	.....	4.00	2.85	2.98	2.75	3.50	2.75	2.80	2.83	3.02	.....	.....
23	.....	.....	2.85	3.02	2.77	3.30	2.78	2.85	2.85	3.02	.....	.....
24	.....	3.62	.....	2.87	2.76	3.10	2.80	2.79	2.85	3.00	.....	.....
25	.....	.....	2.90	2.85	2.75	2.98	2.83	2.77	2.84	3.08	.....	.....
26	3.78	3.62	.....	2.77	2.75	2.71	2.80	2.75	2.87	3.05	.....	.....
27	.....	.....	3.12	2.79	2.75	.....	2.94	2.73	2.82	3.03	.....	.....
28	3.82	3.62	.....	2.83	2.70	3.89	2.81	2.75	2.83	3.00	.....	.....
29	.....	.....	.....	2.89	2.68	3.30	2.79	2.80	2.82	3.02	.....	.....
30	3.80	.....	.....	2.90	2.68	4.64	2.75	2.77	2.85	3.01	.....	.....
31	.....	.....	.....	.....	2.67	.....	2.74	2.73	.....	.....	.....	.....
1899.												
1	.....	.....	.....	.....	1.85	1.68	1.95	1.34	1.61	1.52	.....	.....
2	.....	.....	.....	.....	1.85	1.65	1.83	1.37	1.68	1.58	.....	.....
3	.....	.....	.....	.....	1.83	1.66	1.75	1.38	1.73	1.55	.....	.....
4	.....	.....	.....	.....	1.80	1.62	1.68	1.89	1.57	1.55	.....	.....
5	.....	.....	.....	.....	1.80	1.61	1.68	2.20	1.62	1.57	.....	.....

Mean daily gage height, in feet, of North Loup River near St. Paul, 1895–1903—Con.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1899.												
6					1.75	1.60	1.59	2.08	1.70	1.52		
7					2.30	1.55	1.55	2.05	1.95	1.50		
8					2.32	1.57	1.55	2.01	1.98	1.50		
9					2.07	1.56	1.56	1.88	1.85	1.60		
10					2.00	1.52	1.57	1.80	1.80	1.63		
11					1.95	1.55	1.63	1.92	1.72	1.58		
12					1.83	1.53	1.53	1.74	1.68	1.53		
13					1.72	1.47	1.49	1.92	1.65	1.57		
14					1.72	1.42	1.45	1.86	1.62	1.55		
15					1.68	1.41	2.12	1.65	1.60	2.08		
16					1.71	1.45	2.27	1.65	1.63	2.03		
17					1.73	1.48	2.03	1.57	1.53	1.97		
18				1.81	1.70	1.50	1.92	1.48	1.55	1.69		
19				1.77	1.64	1.50	1.75	1.55	1.50	1.65		
20				1.82	1.68	1.50	1.35	1.57	1.50	1.65		
21				1.73	2.30	1.47	1.37	1.62	1.50	1.60		
22				1.75	2.08	1.50	1.28	1.58	1.51	1.58		
23				1.72	1.93	1.53	1.30	1.57	1.50	1.60		
24				1.80	1.90	2.30	1.28	1.54	1.55	1.60		
25				1.83	1.87	2.00	1.28	1.54	1.52	1.62		
26				1.78	1.85	1.80	1.33	1.55	1.50	1.60		
27				3.20	1.78	3.30	1.32	1.57	1.52	1.65		
28				2.78	1.75	2.54	1.25	1.53	1.55	1.63		
29				2.43	1.77	2.12	1.22	1.54	1.55	1.58		
30				1.87	1.73	2.03	1.33	1.57	1.58	1.57		
31					1.73		1.35	1.59		1.58		
1903.												
1					1.60	1.85	1.50	2.55	1.45	1.40	1.60	1.30
2					1.70	1.90	1.45	2.00	1.40	1.45	1.65	1.25
3					1.65	1.85	2.50	(a)	1.30	1.60	1.60	1.40
4					1.65	1.80	1.80	(a)	1.35	1.40	1.60	1.30
5					1.60	1.80	1.75	(a)	1.40	1.45	1.55	
6					1.65	1.75	1.55	(a)	1.60	1.45	1.50	
7					1.65	1.75	1.45	(a)	1.50	1.80	1.45	
8					1.65	1.70	1.40	(a)	1.60	1.55	1.60	
9					1.65	1.70	1.35	(a)	1.55	1.50	1.65	
10					2.43	1.70	1.35	(a)	1.50	1.40	1.65	
11					1.95	1.70	1.40	1.45	1.50	1.50	1.60	
12					1.90	1.65	1.45	1.50	1.60	1.50	1.60	
13					1.80	1.65	1.40	1.85	1.50	1.55	1.55	
14					1.70	1.65	1.85	1.65	1.50	1.65	1.55	
15				1.45	1.70	1.60	1.65	1.50	1.55	1.60	1.60	
16				1.45	1.70	1.55	1.65	1.45	1.55	1.55	1.55	
17				1.45	1.70	1.55	1.65	1.45	1.45	1.45	.70	
18				1.50	1.65	1.50	1.60	1.50	1.50	1.40	.80	
19				1.55	1.65	1.55	1.75	1.40	1.50	1.45	1.05	
20				1.55	1.60	1.50	1.60	1.50	1.55	1.45	1.30	
21				1.55	1.55	1.55	1.70	1.40	1.45	1.45	1.70	
22				1.60	1.55	1.60	1.60	1.35	1.40	1.50	1.80	
23				1.60	1.85	1.60	1.55	1.35	1.40	1.50	1.85	
24				1.60	1.60	1.60	1.50	2.50	1.35	1.50	1.60	
25				1.65	1.60	1.65	1.50	2.10	1.35	1.55	1.55	
26				1.55	1.80	1.65	1.45	2.65	1.35	1.50	1.55	
27				1.50	1.70	1.55	1.45	1.90	1.30	1.55	1.50	
28				1.60	1.60	1.50	1.40	1.60	1.35	1.60	1.60	
29				1.90	1.80	1.50	2.68	1.50	1.40	1.55	1.35	
30				1.65	2.00	1.45		1.50	1.50	1.55	1.35	
31					1.95			1.48		1.60		

a Sand on gage rod.

Mean daily discharge, in second-feet, of North Loup River near St. Paul, 1895–1903.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1895.								
1	.....	.....	1,453	1,017	702	987	1,137	987
2	.....	.....	1,456	958	842	987	1,137	1,857
3	.....	.....	3,766	1,107	900	842	1,231	1,293
4	.....	.....	1,952	958	1,293	648	1,293	1,293
5	.....	1,520	1,787	900	1,047	702	1,293	1,293
6	.....	1,486	1,357	842	987	758	1,453	1,200
7	.....	1,421	1,453	1,047	900	702	1,293	1,262
8	.....	1,293	1,453	958	702	987	1,262	1,200
9	.....	1,137	1,618	987	1,618	702	1,231	1,137
10	.....	1,293	1,453	987	1,453	900	1,293	1,047
11	.....	1,618	1,618	987	900	871	1,293	987
12	.....	1,421	1,618	958	702	702	1,293	987
13	.....	1,293	1,357	1,077	1,618	702	1,293	900
14	.....	1,293	1,387	1,107	1,137	648	1,325	758
15	.....	1,293	1,293	1,107	987	1,077	1,293	842
16	.....	1,137	1,357	987	1,077	1,351	1,351	842
17	.....	1,137	1,787	900	987	1,047	1,389	702
18	.....	1,168	1,618	842	758	1,107	1,293	758
19	.....	987	987	814	702	929	1,293	702
20	.....	1,047	1,137	842	675	1,137	1,040	702
21	.....	987	987	702	702	1,047	958	566
22	.....	842	987	842	702	3,991	987	.....
23	.....	871	1,047	842	1,787	1,787	987	.....
24	.....	842	1,077	842	1,389	1,293	900	.....
25	.....	929	987	702	702	1,293	928	.....
26	.....	842	1,047	675	648	1,262	928	.....
27	.....	871	1,230	620	593	1,200	842	.....
28	.....	929	1,325	437	842	1,137	900	.....
29	.....	871	1,137	566	702	1,017	842	.....
30	.....	1,962	1,200	566	1,453	987	900	.....
31	.....	1,618	.....	620	987	.....	842	.....
1896.								
1	1,076	1,521	1,698	1,138	1,072	860	949	.....
2	1,139	1,455	1,455	1,110	992	843	965	.....
3	930	1,233	1,139	1,120	957	835	915	.....
4	1,078	1,263	1,139	1,080	992	883	932	.....
5	844	1,263	1,170	1,080	974	890	932	.....
6	987	1,139	4,100	1,072	949	908	923	.....
7	1,139	1,047	2,825	1,100	915	932	923	.....
8	987	987	1,540	1,128	932	883	940	.....
9	909	1,139	1,340	1,460	957	851	940	.....
10	844	987	1,260	1,350	860	883	940	.....
11	844	901	1,337	1,200	850	860	940	.....
12	2,519	958	1,290	1,128	890	908	965	.....
13	1,962	901	1,270	1,120	900	932	983	.....
14	1,455	930	1,230	1,128	883	1,016	949	.....
15	1,553	901	1,200	1,090	900	1,000	949	.....
16	1,263	1,078	1,165	1,048	867	883	949	.....
17	1,455	1,203	1,155	1,032	875	908	923	.....
18	3,767	987	1,147	1,056	900	957	915	.....
19	1,962	873	1,257	1,072	843	1,016	965	.....
20	1,293	987	1,330	1,064	835	983	965	.....
21	958	844	1,540	1,032	867	940	949	.....
22	958	901	1,930	1,008	890	890	923	.....
23	1,048	958	1,590	1,016	875	867	940	.....
24	958	930	1,530	1,056	890	932	923	.....
25	901	901	1,560	991	867	923	888	.....
26	844	702	1,370	1,184	867	949	837	.....
27	779	2,327	1,370	983	867	923	880	.....
28	1,139	759	1,300	1,056	890	923	940	.....
29	1,962	570	1,212	923	900	890	1,220	.....
30	1,618	702	1,184	1,184	883	923	1,220	.....
31	.....	873	.....	1,155	890	.....	1,120	.....
1897.								
1	1,150	1,250	880	1,680	640	610	740	.....
2	1,460	1,220	905	1,360	620	610	740	.....
3	3,300	1,180	940	1,890	620	690	760	.....
4	3,530	1,210	990	1,030	620	650	720	.....
5	920	1,180	960	1,030	670	650	720	.....

Mean daily discharge, in second-feet, of North Loup River near St. Paul, 1895–1903—Con.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1897.								
6	920	1,180	930	890	630	680	740	.....
7	690	1,190	900	860	900	690	770	.....
8	460	1,140	920	800	790	690	770	.....
9	690	1,160	890	690	770	600	800	.....
10	460	1,100	860	740	780	1,100	820	.....
11	1,690	1,100	850	750	740	800	820	.....
12	1,690	1,080	840	740	690	780	820	.....
13	1,690	1,060	840	780	670	770	860	.....
14	1,690	1,110	930	740	690	740	900	.....
15	1,460	1,080	970	690	670	720	920	.....
16	1,460	1,080	960	620	570	720	1,000	.....
17	1,460	1,050	905	720	720	690	1,260	.....
18	1,150	1,030	990	680	730	690	1,210	.....
19	1,460	1,020	930	780	690	690	1,020	.....
20	1,280	1,030	900	700	670	700	1,130	.....
21	1,320	1,020	740	680	670	700	1,080	.....
22	1,360	1,020	1,430	650	650	680	1,080	.....
23	1,400	1,030	1,230	670	690	690	1,100	.....
24	1,230	1,030	1,050	680	640	690	1,100	.....
25	1,210	1,030	940	690	630	690	1,200	.....
26	1,130	1,040	720	670	610	710	1,210	.....
27	1,140	1,040	.....	770	590	670	1,230	.....
28	1,170	1,010	1,770	670	610	680	1,230	.....
29	1,210	970	1,200	650	650	670	1,290	.....
30	1,210	940	2,550	610	630	700	1,320	.....
31	.....	915	.....	620	590	.....	.....	.....
1899.								
1	.....	1,310	1,056	2,250	743	949	118	.....
2	.....	1,270	1,040	1,600	767	940	867	.....
3	.....	1,226	1,056	1,166	776	966	843	.....
4	.....	1,184	1,040	1,090	1,201	818	843	.....
5	.....	1,166	1,040	1,900	1,500	851	859	.....
6	.....	1,099	1,040	1,016	1,380	915	818	.....
7	.....	1,610	1,000	983	1,340	1,128	801	.....
8	.....	1,590	1,016	983	1,300	1,156	801	.....
9	.....	1,330	1,008	992	1,184	1,048	883	.....
10	.....	1,251	975	1,000	1,109	1,008	907	.....
11	.....	1,192	1,000	1,048	1,218	949	867	.....
12	.....	1,064	983	966	1,072	915	827	.....
13	.....	966	932	932	1,243	899	859	.....
14	.....	957	891	899	1,201	875	843	.....
15	.....	915	883	1,510	1,024	867	1,300	.....
16	.....	932	915	1,660	1,032	891	1,251	.....
17	.....	940	940	1,410	975	818	1,201	.....
18	1,680	915	957	1,300	907	835	958	.....
19	1,610	867	957	1,147	975	793	924	.....
20	1,630	907	949	810	1,000	793	924	.....
21	1,500	1,490	924	827	1,040	793	883	.....
22	1,490	1,280	949	750	1,008	801	867	.....
23	1,430	1,156	974	759	1,000	793	883	.....
24	1,470	1,146	1,700	736	975	835	883	.....
25	1,470	1,127	1,400	736	966	818	899	.....
26	1,380	1,127	1,200	767	958	801	883	.....
27	2,925	1,064	7,500	759	966	818	924	.....
28	2,356	1,064	5,050	701	915	843	907	.....
29	1,940	1,090	3,700	672	907	843	867	.....
30	1,350	1,071	2,900	743	915	867	859	.....
31	.....	1,080	.....	759	915	.....	867	.....
1903.								
1	.....	1,180	1,560	810	4,070	890	700	1,290
2	.....	1,420	1,700	750	2,270	810	810	1,420
3	.....	1,290	1,560	3,560	.....	700	1,070	1,290
4	.....	1,290	1,420	1,700	.....	750	750	1,290
5	.....	1,180	1,420	1,290	.....	810	810	1,180
6	.....	1,180	1,290	890	.....	1,180	810	1,070
7	.....	1,180	1,290	750	.....	980	1,560	1,070
8	.....	1,180	1,180	700	.....	1,180	980	1,420
9	.....	1,180	1,180	650	.....	1,070	890	1,560
10	.....	.....	1,180	650	.....	980	750	1,560

Mean daily discharge, in second-feet, of North Loup River near St. Paul, 1895–1903—Con.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1903.								
11		1,980	1,180	700	980	980	890	1,420
12		1,840	1,070	750	1,070	1,180	890	1,420
13		1,420	1,070	700	1,980	810	980	1,290
14		1,180	1,070	1,560	1,420	810	1,290	1,290
15	1,070	1,180	980	1,070	1,070	890	1,180	1,420
16	1,070	1,180	890	1,070	980	890	1,070	1,290
17	1,070	1,180	890	1,070	980	750	890	400
18	1,180	1,070	810	980	1,070	810	810	480
19	1,290	1,070	890	1,290	890	810	890	610
20	1,290	980	810	980	1,070	890	890	810
21	1,290	890	890	1,180	890	750	890	1,840
22	1,290	890	980	1,070	810	700	980	2,120
23	1,290	1,560	980	980	810	700	980	2,270
24	1,290	980	980	890	4,070	650	980	1,560
25	1,420	980	1,070	890	2,570	650	1,070	1,420
26	1,180	1,420	1,070	810	4,410	650	1,070	1,420
27	1,070	1,180	890	890	1,980	610	1,180	1,420
28	1,290	980	810	810	1,180	650	1,290	1,700
29	1,980	1,420	810	4,500	980	700	1,180	1,070
30	1,290	1,980	750	.....	980	810	1,180	1,070
31	.....	1,840	.....	.....	980	.....	1,290	.....

Estimated monthly discharge of North Loup River near St. Paul, 1895–1903.

[Drainage area, 4,020 square miles.]

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
April.								
1896	3,770	779	1,305	77,600	0.324	0.36	6	5.68
1897	3,530	575	1,329	79,100	.330	.37	8	4.63
1899 [a]	2,920	1,350	1,711	44,100	.....	.....	.....	1.00
1903 [b]	1,980	1,070	1,273	40,400	.....	.....	.....	2.03
May.								
1895	1,960	842	1,189	73,100	.295	.34	13	2.48
1896	2,330	570	1,040	63,900	.258	.30	10	3.02
1897	1,260	915	1,080	66,400	.269	.31	43	.72
1899	1,610	867	1,141	70,200	.283	.32	11	2.79
1903	1,980	890	1,276	75,900	.317	.35	5	6.56
June.								
1895	4,460	987	1,531	91,100	.380	.42	9	4.76
1896	4,100	1,139	1,494	88,900	.371	.41	6	6.65
1897	2,550	720	1,032	61,400	.256	.29	50	.57
1899	7,500	883	1,533	91,200	.380	.43	9	4.61
1903	1,700	750	1,089	64,800	.271	.30	14	2.14
July.								
1895	1,110	437	864	53,100	.215	.25	26	.98
1896	1,460	923	1,102	67,800	.274	.32	9	3.70
1897	1,890	610	824	50,700	.204	.23	14	1.60
1899	2,250	672	1,034	63,600	.256	.30	15	2.00
1903	4,500	650	1,170	72,000	.291	.34	5	7.22
August.								
1895	1,790	593	984	60,500	.244	.28	6	2.49
1896	1,070	835	904	55,600	.225	.26	31	.85
1897	900	610	675	41,500	.168	.19	7	2.63
1899	1,500	743	1,049	64,500	.261	.30	8	3.58
1903	4,410	810	1,631	100,300	.405	.47	8	6.12
September.								
1895	3,990	648	1,094	65,100	.272	.30	17	1.81
1896	1,020	835	913	54,300	.227	.25	12	2.07
1897	1,100	610	705	41,900	.175	.19	23	.84
1899	1,160	793	888	52,800	.221	.24	34	.70
1903	1,180	610	835	49,700	.208	.23	68	.34

[a] April 18 to 30.

[b] April 15 to 30.

Estimated monthly discharge of North Loup River near St. Paul, 1895–1903—Cont'd.

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
October.								
1895	1,450	842	1,146	70,500	0.285	0.33	165	0.20
1896	1,220	837	958	58,900	.238	.27	12	2.19
1897	1,320	720	979	60,200	.243	.28	6	4.56
1899	1,300	801	907	55,800	.225	.26	87	.30
1903	1,560	700	997	61,300	.248	.30	24	1.27
November.								
1895	1,860	566	1,015	60,400	.252	.28	32	.84
1903	2,270	400	1,316	78,300	.327	.36	60	.60

MIDDLE LOUP RIVER AT ST. PAUL.

Observations begun at St. Paul May 5, 1895, were suspended from time to time, and the records cover only the open seasons for the years 1895 to 1897, inclusive, 1899, and 1903. The station is located at the combination railroad and highway bridge 1 mile south of St. Paul, in sec. 10, T. 15 N., R. 10 W. The location is shown on the St. Paul topographic atlas sheet.

Refined measurements have not been possible at this station on account of the shifting sandy bed and the obstructions from old piling in the channel; neither has it been practicable to obtain records of winter flow.

Owing to the changeable nature of the river channel a number of gages have been necessary at this station. During the period from 1895 to 1897 the gage was an inclined staff on the right bank just below the bridge, with its datum 7.35 feet below a standard United States Geological Survey bench mark, 50 feet southeast of the right approach. On April 18, 1899, a second inclined staff was installed on the right bank 130 feet downstream from the bridge. The channel soon shifted to the opposite shore, and on June 7, 1899, a third inclined gage was installed on the left bank 200 feet downstream. The two later gages had the same datum, 7.54 feet below the standard bench mark described above. During 1903 a vertical staff gage was spiked to a downstream piling near the center of the bridge. Its datum was maintained the same as that of the two gages used during 1899, namely, 7.54 feet below the bench mark described. As the gages were located at different sections of the channel, no attempt has been made to refer the readings during the several periods to the same datum.

Discharge measurements of Middle Loup River at St. Paul, 1895–1903.

Date.	Hydrographer.	Gage height.	Discharge.
1895.		*Feet.*	*Sec.-ft.*
June 28	O. V. P. Stout	1.77	1,046
September 7	do	1.62	863
1896.			
May 8	E. N. Carbin	1.36	940
June 11	O. V. P. Stout	1.24	1,400
July 9	E. F. Youngfelt	1.42	1,332
August 21	do	1.42	984
September 23	do	1.53	1,015
1897.			
April 21	Adna Dobson	1.74	1,792
May 11	do	1.77	1,441
May 27	do	1.84	1,256
June 18	O. V. P. Stout	1.87	979
July 16	do	1.58	816
July 27	do	1.56	666
August 18	do	1.65	661
October 9	Adna Dobson	1.70	814
October 30	do	1.68	1,671
1899.		*Feet.*	*Sec.-ft.*
April 18	Glenn E. Smith	2.10	988
May 4	do	1.84	969
May 18	do	1.70	1,186
June 7	do	2.30	920
June 27	do	4.20	14,631
July 20	do	2.18	888
August 7	do	2.68	1,612
August 23	do	2.20	1,113
September 7	do	2.25	983
September 19	do	2.40	1,112
September 20	Adna Dobson	2.25	988
1903.			
April 7	J. C. Stevens		2,184
April 16	do	2.43	1,364
May 14	do	2.30	1,764
June 2	do	2.75	2,772
August 11	do	2.68	1,761
September 21	E. C. Murphy	2.41	1,170

Mean daily gage height, in feet, of Middle Loup River at St. Paul, 1895–1903.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1895.												
1						2.40	1.80	1.62	1.82	1.53	1.78	
2						2.39	1.77	1.61	1.75	1.52	1.72	
3						3.21	1.74	1.61	1.74	1.53	1.70	
4						2.78	1.74	1.60	1.70	1.58	1.70	
5					1.96	2.45	1.78	1.72	1.69	1.62	1.74	
6					1.93	2.15	1.72	1.61	1.65	1.65	1.70	
7					1.89	1.92	1.71	1.62	1.62	1.62	1.71	
8					1.81	1.81	1.70	1.64	1.58	1.62	1.65	
9					1.75	1.76	1.64	1.50	1.58	1.64	1.60	
10					1.75	1.81	1.63	1.51	1.56	1.55	1.51	
11					1.78	1.83	1.61	1.63	1.52	1.59	1.47	
12					1.79	1.85	1.59	1.61	1.50	1.58	1.46	
13					1.83	1.82	1.63	1.84	1.53	1.56	1.42	
14					1.84	1.81	1.75	1.81	1.52	1.62	1.75	
15					1.82	1.76	1.70	1.94	1.51	1.67	1.73	
16					1.80	1.78	1.65	1.93	1.60	1.67	1.57	
17					1.83	1.97	1.60	1.81	1.62	1.65	1.52	
18					1.82	2.07	1.50	1.71	1.63	1.61	1.35	
19					1.82	1.92	1.54	1.70	1.65	1.60	1.25	
20					1.86	1.89	1.55	1.71	1.59	1.58	1.30	
21					1.85	1.86	1.55	1.61	1.82	1.60	1.12	
22					1.85	1.78	1.60	1.62	1.87	1.63	1.11	
23					1.83	1.69	1.65	1.90	2.27	1.63	1.03	
24					1.83	1.70	1.70	1.73	1.90	1.72	1.46	
25					1.86	1.72	1.68	1.74	1.73	1.72	1.45	
26					1.87	1.65	1.67	1.84	1.67	1.72	1.60	
27					1.83	1.63	1.65	1.83	1.58	1.74	1.80	
28					1.77	1.77	1.60	1.84	1.55	1.80	2.15	
29					1.70	1.89	1.64	1.82	1.58	1.87	2.54	
30					1.94	1.83	1.61	1.91	1.53	1.68	2.86	
31					2.12		1.60	1.81		1.80		
1896.												
1				1.73	1.64	1.90	1.35	1.62	1.30	1.50	1.47	
2				1.63	1.53	1.78	1.30	1.58	1.31	1.55	1.22	
3				1.43	1.44	1.70	1.32	1.45	1.35	1.45	1.25	
4				1.42	1.52	1.72	1.33	1.40	1.40	1.42	1.22	
5				1.43	1.43	1.59	1.34	1.43	1.32	1.50	1.15	
6				1.33	1.33	1.54	1.31	1.39	1.45	1.52	1.30	
7				1.42	1.41	3.35	1.26	1.30	1.30	1.45	1.52	2.84
8				1.51	1.31	1.85	1.20	1.31	1.31	1.50	1.68	3.00
9				1.61	1.64	1.53	1.34	1.30	1.32	1.42	1.52	3.00
10				1.53	1.41	1.35	1.67	1.35	1.47	1.53	1.18	2.98

Mean daily gage height, in feet, of Middle Loup River at St. Paul, 1895–1903—Cont'd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1896.												
11				1.43	1.32	1.27	1.47	1.38	1.54	1.55	1.20	2.90
12				1.82	1.42	1.27	1.38	1.36	1.50	1.50	1.24	2.88
13				1.94	1.44	1.20	1.34	1.30	1.52	1.45	1.35	2.87
14				1.83	1.50	1.20	1.29	1.34	1.65	1.50	1.48	2.87
15				1.54	1.45	1.35	1.26	1.34	1.61	1.55	1.52	2.83
16				1.62	1.69	1.38	1.27	1.35	1.55	1.43	1.57	2.83
17				1.64	1.60	1.36	1.30	1.29	1.54	1.43	1.25	2.80
18				2.11	1.57	1.34	1.33	1.35	1.50	1.45	1.55	.....
19				2.40	1.51	1.39	1.32	1.34	1.55	1.50	1.62	.....
20				1.84	1.54	1.35	1.33	1.40	1.60	1.53	1.15	1.95
21				1.42	1.61	1.47	1.38	1.43	1.62	1.45	1.20	1.98
22				1.32	1.44	1.45	1.36	1.44	1.55	1.51	1.35	2.00
23				1.51	1.51	1.43	1.35	1.34	1.53	1.44	1.68	.....
24				1.54	1.45	1.56	1.40	1.31	1.45	1.50	2.05	1.85
25				1.63	1.51	1.60	1.40	1.35	1.50	1.43	2.21	1.76
26				1.34	1.54	1.48	1.48	1.30	1.55	1.52	2.75	1.72
27				1.53	1.53	1.41	1.53	1.25	1.55	1.50	2.80	.....
28				1.60	1.40	1.40	1.50	1.30	1.61	1.45	2.60	1.57
29			1.70	1.90	1.54	1.33	1.42	1.34	1.65	1.75	.....	1.60
30			1.62	1.94	1.44	1.40	1.39	1.25	1.60	1.84	2.75	1.74
31			1.63		1.63		1.62	1.23		1.53		1.74
1897.												
1	1.50	2.40	.....	1.78	1.43	1.66	2.64	1.42	1.67	1.60	.....	.....
2	1.20	.....	2.26	1.95	1.50	1.69	2.60	1.48	1.60	1.58	.....	.....
3	.....	.....	3.59	2.40	1.54	1.94	2.17	1.50	1.55	1.65	.....	.....
4	.....	2.35	3.20	2.35	1.60	1.86	1.85	1.49	1.48	1.72	.....	.....
5	.....	.....	.....	1.80	1.65	1.86	1.75	1.67	1.50	1.76	.....	.....
6	2.00	.....	.....	1.95	1.68	1.67	1.68	1.75	1.62	1.68	.....	.....
7	2.20	.....	3.61	1.89	1.65	1.76	1.65	1.71	1.44	1.65	.....	.....
8	2.45	2.31	.....	1.78	1.70	1.75	1.58	1.95	1.38	1.67	.....	.....
9	2.57	.....	.....	1.63	1.78	1.74	1.55	1.92	1.43	1.64	.....	.....
10	.....	.....	3.00	1.66	1.75	1.79	1.69	2.25	1.74	1.78	.....	.....
11	2.89	.....	2.26	1.80	1.77	1.90	1.70	1.78	1.70	1.82	.....	.....
12	.....	2.33	1.45	2.25	1.72	1.85	1.78	1.85	1.73	1.80	.....	.....
13	2.88	.....	.....	2.03	1.78	1.77	1.72	1.77	1.76	1.68	.....	.....
14	2.87	.....	.....	2.25	1.76	1.80	1.55	1.75	1.71	1.80	.....	.....
15	2.70	.....	1.50	2.05	1.63	1.86	1.50	1.73	1.74	1.72	.....	.....
16	.....	2.30	.....	1.90	1.65	1.84	1.47	1.68	1.72	1.83	.....	.....
17	.....	.....	2.10	1.90	1.67	1.89	1.53	1.64	1.65	1.90	.....	.....
18	.....	2.38	2.10	1.65	1.77	1.87	1.60	1.60	1.63	1.90	.....	.....
19	2.47	.....	1.85	1.60	1.73	1.83	1.61	1.66	1.68	1.86	.....	.....
20	.....	2.74	1.86	1.63	1.68	1.68	1.72	1.63	1.65	1.80	.....	.....
21	.....	.....	.....	1.75	1.86	1.70	1.67	1.65	1.67	1.73	.....	.....
22	.....	.....	1.91	1.70	1.68	1.75	1.64	1.64	1.69	1.75	.....	.....
23	.....	.....	1.90	1.58	1.80	1.77	1.71	1.67	1.70	1.78	.....	.....
24	.....	2.15	.....	1.77	1.73	1.68	1.68	1.65	1.68	1.76	.....	.....
25	.....	.....	1.70	1.86	1.77	1.70	1.68	1.51	1.65	1.73	.....	.....
26	2.40	2.00	1.70	1.78	1.73	1.87	1.70	1.48	1.71	2.20	.....	.....
27	.....	.....	.....	1.80	1.83	1.92	1.58	1.50	1.64	2.55	.....	.....
28	.....	.....	.....	1.75	1.78	1.79	1.55	1.56	1.68	1.98	.....	.....
29	.....	.....	.....	1.88	1.75	1.77	1.67	1.64	1.50	1.80	.....	.....
30	.....	.....	.....	1.60	1.67	3.11	1.65	1.72	1.56	1.50	.....	.....
31	.....	.....	1.69	.....	1.68	.....	1.58	1.75	.....	1.77	.....	.....
1899.												
1	.....	.....	.....	.....	1.76	1.59	2.00	2.24	2.29	2.24	.....	.....
2	.....	.....	.....	.....	1.80	1.41	1.87	2.12	2.29	2.20	.....	.....
3	.....	.....	.....	.....	1.79	1.40	1.90	2.16	2.33	2.35	.....	.....
4	.....	.....	.....	.....	1.81	1.62	1.90	3.10	2.19	2.34	.....	.....
5	.....	.....	.....	.....	1.95	1.53	2.12	2.74	2.16	2.37	.....	.....
6	.....	.....	.....	.....	1.82	1.44	2.78	2.70	2.21	2.40	.....	.....
7	.....	.....	.....	.....	1.90	1.54	3.17	2.65	2.18	2.37	.....	.....
8	.....	.....	.....	.....	2.08	1.29	2.71	2.57	2.28	2.34	.....	.....
9	.....	.....	.....	.....	1.93	1.32	2.42	2.66	2.32	2.36	.....	.....
10	.....	.....	.....	.....	1.87	1.25	2.16	2.25	2.34	2.36	.....	.....
11	.....	.....	.....	.....	1.81	1.24	2.12	2.20	2.34	2.34	.....	.....
12	.....	.....	.....	.....	1.78	1.20	2.09	2.18	2.32	2.37	.....	.....
13	.....	.....	.....	.....	1.75	1.33	2.18	2.13	2.28	2.36	.....	.....
14	.....	.....	.....	.....	1.75	1.32	3.10	2.25	2.25	2.40	.....	.....
15	.....	.....	.....	.....	1.60	1.31	2.65	2.39	2.30	2.39	.....	.....

Mean daily gage height, in feet, of Middle Loup River at St. Paul, 1895–1903—Cont'd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1899.												
16					1.62	1.32	2.55	2.36	2.30	2.49		
17					1.62	1.30	2.36	2.31	2.40	2.47		
18				2.10	1.72	1.28	2.20	2.30	2.38	2.49		
19				2.09	1.66	1.19	2.12	2.27	2.36	2.42		
20				2.12	1.70	1.15	2.12	2.21	2.30	2.40		
21				2.09	1.80	1.32	2.09	2.20	2.30	2.41		
22				2.10	2.15	1.34	2.11	2.15	2.30	2.42		
23				2.00	2.05	1.29	2.12	2.20	2.30	2.41		
24				2.00	1.70	1.29	2.15	2.20	2.27	2.40		
25				2.03	1.68	2.34	2.06	2.15	2.26	2.45		
26				2.60	1.60	4.17	2.02	2.19	2.24	2.42		
27				2.12	1.83	3.51	2.06	2.16	2.27	2.45		
28				2.39	1.92	3.30	2.30	2.12	2.26	2.44		
29				2.00	1.66	2.84	2.20	2.10	2.24	2.47		
30				1.74	1.49	2.35	2.10	2.13	2.22	2.49		
31					1.84		2.42	2.21		2.49		
1903.												
1					2.56	2.85	2.55	3.50	2.50	2.40	2.35	
2					2.55	2.80	2.55	3.50	2.40	2.53	2.55	
3					2.55	2.70	2.90	3.00	2.40	2.45	2.55	
4					2.48	2.60	3.88	2.65	2.40	2.50	2.30	
5					2.48	2.70	3.05	2.45	2.40	2.55	2.25	
6					2.50	2.60	2.70	2.30	2.50	2.60	2.20	
7					2.50	2.65	2.55	2.20	2.40	2.60	2.20	
8					2.55	2.62	2.45	2.20	2.50	2.60	2.20	
9					2.48	2.60	2.40	2.45	2.50	2.50	2.20	
10					2.45	2.55	2.45	2.40	2.55	2.40	2.20	
11					2.80	2.55	2.45	2.65	2.50	2.25	2.20	
12					2.74	2.55	2.35	2.82	2.40	2.25	2.20	
13					2.64	2.50	2.35	3.15	2.55	2.65	2.25	
14					2.30	2.50	2.72	2.87	2.60	2.50	2.25	
15					2.15	2.50	2.77	2.70	2.55	2.45	2.20	
16				2.55	2.35	2.55	2.65	2.75	2.50	2.40	2.30	
17				2.37	2.35	2.55	2.75	2.95	2.50	2.30	2.30	
18				2.37	2.35	2.50	2.65	2.60	2.50	2.25	1.70	
19				2.40	2.50	2.50	2.55	2.70	2.45	2.25	1.90	
20				2.58	2.40	2.50	2.55	2.50	2.40	2.20	2.00	
21				2.70	2.55	2.45	2.45	2.40	2.40	2.20	2.10	
22				2.51	2.40	2.58	2.40	2.40	2.40	2.20		
23				2.50	2.90	2.50	2.40	2.40	2.45	2.20		
24				2.50	2.87	2.72	2.40	2.40	2.45	2.20		
25				2.50	2.75	2.98	2.35	3.35	2.40	2.25		
26				2.50	2.85	2.80	2.30	3.75	2.40	2.25		
27				2.40	2.97	2.75	2.30	3.85	2.45	2.30		
28				2.42	2.70	2.65	2.30	3.60	2.40	2.20		
29				2.09	3.04	2.65	2.45	3.20	2.45	2.20		
30				2.58	3.93	2.65	2.77	2.90	2.45	2.25		
31					3.30		2.70	2.55		2.25		

Mean daily discharge, in second-feet, of Middle Loup River at St. Paul, 1895–1903.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1895.								
1			1,520	1,100	803	1,134	662	
2			2,200	1,050	785	1,018	644	
3			3,965	1,000	787	1,000	622	
4			2,987	1,000	771	933	740	
5		1,380	2,300	1,066	767	917	803	
6		1,325	1,723	967	787	850	850	
7		1,254	1,307	950	803	803	803	
8		1,117	1,117	993	835	740	803	
9		1,018	1,032	835	614	740	835	
10		1,018	1,117	820	630	707	695	
11		1,066	1,151	787	820	645	755	
12		1,083	1,185	755	787	614	740	
13		1,151	1,134	820	1,168	662	707	
14		1,168	1,117	1,018	1,117	645	803	
15		1,134	1,132	933	1,343	630	883	

Mean daily discharge, in second-feet, of Middle Loup River at St. Paul, 1895–1903—Con.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1895.								
16		1,100	1,166	850	1,325	770	883	
17		1,151	1,393	771	1,117	803	840	
18		1,134	1,570	614	950	820	787	
19		1,134	1,307	678	933	850	771	
20		1,202	1,254	694	950	755	740	
21		1,185	1,202	694	787	1,134	771	
22		1,185	1,066	771	803	1,220	820	
23		1,151	917	850	1,270	1,950	820	
24		1,151	933	933	985	1,270	967	
25		1,202	967	900	1,000	985	967	
26		1,219	850	885	1,168	833	967	
27		1,151	820	850	1,151	740	1,000	
28		1,050	1,050	771	1,168	695	1,100	
29		933	1,254	835	1,134	740	1,220	
30		1,334	1,151	787	1,290	662	900	
31		1,666		771	1,117		1,100	
1896.								
1	1,490	1,440	1,720	1,315	1,685	806	970	
2	1,360	1,300	1,550	1,240	1,550	806	1,022	
3	1,060	1,150	1,430	1,270	1,450	854	914	
4	1,020	1,230	1,460	1,270	1,200	914	880	
5	1,030	1,050	1,290	1,270	1,210	818	985	
6	900	900	1,215	1,195	1,125	962	1,010	
7	1,020	1,015		1,080	955	782	930	
8	1,170	870	2,250	960	942	794	1,000	
9	1,310	1,360	1,775	1,332	900	806	914	
10	1,200	1,015	1,515	1,770	955	974	1,046	
11	1,050	890	1,400	1,420	980	1,058	1,082	
12	1,800	1,030	1,465	1,270	942	1,010	1,010	
13	1,700	1,060	1,300	1,300	840	1,034	974	
14	1,230	1,150	1,300	1,100	885	1,190	1,034	
15	1,310	1,080	1,560	1,040	870	1,142	1,110	
16	1,330	1,440	1,590	1,050	890	1,070	962	
17	1,060	1,300	1,540	1,110	810	1,058	974	
18	2,000	1,260	1,485	1,170	890	1,000	1,000	
19	2,430	1,165	1,560	1,160	870	1,058	1,070	
20	1,730	1,210	1,470	1,170	955	1,118	1,106	
21	1,070	1,310	1,660	1,260	984	1,130	1,010	
22	910	1,080	1,650	1,220	1,000	1,046	1,082	
23	1,170	1,170	1,580	1,210	880	1,015	1,000	
24	1,210	1,080	1,795	1,300	840	926	1,070	
25	1,340	1,170	1,820	1,300	880	985	985	
26	1,000	1,210	1,645	1,450	820	1,034	1,094	
27	1,190	1,200	1,505	1,540	760	1,034	1,070	
28	1,300	1,000	1,417	1,480	820	1,106	1,010	
29	1,860	1,215	1,315	1,320	855	1,154	1,370	
30	1,860	1,070	1,455	1,280	746	1,094	1,478	
31		1,345		1,670	720		1,106	
1897.								
1	1,970	1,210	1,030	1,800	605	670	710	
2	2,500	1,270	1,040	1,740	625	650	705	
3	3,920	1,290	1,240	1,220	625	602	735	
4	3,600	1,350	1,140	955	620	615	765	
5	1,970	1,380	1,130	895	685	620	785	
6	2,000	1,410	960	866	700	855	770	
7	2,300	1,360	1,015	845	685	600	770	
8	1,970	1,410	1,000	815	755	585	790	
9	1,330	1,490	990	800	745	600	795	
10	1,600	1,440	1,005	865	885	690	870	
11	1,970	1,440	1,080	870	707	685	900	
12	3,270	1,360	1,020	915	720	700	900	
13	2,700	1,410	960	880	700	705	870	
14	3,400	1,360	960	800	690	695	960	
15	2,850	1,200	1,000	780	685	705	965	
16	2,300	1,200	970	815	670	700	1,040	
17	2,300	1,200	990	780	655	680	1,140	
18	1,500	1,300	970	790	645	675	1,170	
19	1,330	1,240	945	780	660	690	1,170	
20	1,800	1,180	860	805	650	685	1,150	

Mean daily discharge, in second-feet, of Middle Loup River at St. Paul, 1895–1903—Con.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1897.								
21	1,780	1,350	870	770	660	695	1,140	.....
22	1,780	1,150	895	745	655	705	1,200	.....
23	1,540	1,260	905	755	670	710	1,290	.....
24	1,760	1,180	860	735	660	705	1,340	.....
25	1,880	1,210	870	720	620	700	1,370	.....
26	1,720	1,160	970	715	610	720	2,130	.....
27	1,730	1,250	1,005	670	615	705	2,800	.....
28	1,620	1,190	920	660	605	720	1,900	.....
29	1,800	1,140	905	690	660	670	1,760	.....
30	1,420	1,060	2,600	685	685	695	1,440	.....
31	.....	1,055	.....	660	690	.....	1,840	.....
1899.								
1	.....	877	706	855	1,035	1,074	983	.....
2	.....	907	628	780	964	1,057	958	.....
3	.....	818	610	785	1,005	1,074	1,040	.....
4	.....	945	667	820	2,133	964	1,057	.....
5	.....	1,050	684	1,420	1,659	938	1,083	.....
6	.....	970	616	1,920	1,610	964	1,110	.....
7	.....	1,043	634	1,300	1,568	938	1,083	.....
8	.....	1,240	579	1,035	1,468	1,005	1,057	.....
9	.....	1,119	568	861	1,593	1,035	1,074	.....
10	.....	1,110	547	843	1,137	1,050	1,074	.....
11	.....	1,092	883	835	1,092	1,050	1,057	.....
12	.....	1,101	860	883	1,074	1,035	1,083	.....
13	.....	1,110	938	1,800	1,043	1,013	1,074	.....
14	.....	1,101	931	1,250	1,146	990	1,110	.....
15	.....	1,035	925	1,155	1,294	1,028	1,101	.....
16	.....	1,083	931	998	1,261	1,028	1,193	.....
17	.....	1,101	919	895	1,212	1,110	1,174	.....
18	990	1,203	913	856	1,203	1,092	1,193	.....
19	930	1,137	860	856	1,174	1,074	1,128	.....
20	1,020	1,137	843	843	1,119	1,028	1,110	.....
21	1,005	1,183	938	856	1,110	1,028	1,119	.....
22	1,020	1,518	951	865	1,065	1,028	1,128	.....
23	958	1,327	919	895	1,110	1,028	1,119	.....
24	971	958	919	847	1,119	1,005	1,110	.....
25	998	907	951	833	1,058	998	1,155	.....
26	976	834	1,400	856	1,083	983	1,128	.....
27	1,083	877	3,900	1,020	1,050	1,005	1,155	.....
28	1,372	938	2,610	958	1,013	998	1,146	.....
29	1,013	784	1,800	.....	983	983	1,174	.....
30	856	706	1,155	925	990	971	1,193	.....
31	.....	796	.....	1,184	1,035	.....	1,193	.....
1903.								
1	.....	1,970	3,500	1,550	8,300	1,430	1,250	1,160
2	.....	2,300	3,100	1,550	8,300	1,250	1,550	1,550
3	.....	2,300	2,300	3,500	4,300	1,250	1,340	1,550
4	.....	1,970	1,820	12,000	1,820	1,250	1,430	1,100
5	.....	1,970	2,300	4,700	1,340	1,250	1,550	1,050
6	.....	1,970	1,820	1,970	1,100	1,430	1,670	1,000
7	.....	2,300	1,820	1,550	1,000	1,250	1,670	1,000
8	.....	2,700	1,670	1,340	1,000	1,430	1,670	1,000
9	.....	2,300	1,670	1,250	1,340	1,430	1,430	1,000
10	.....	1,970	1,550	1,340	1,250	1,550	1,250	1,000
11	.....	5,100	1,550	1,340	1,820	1,430	1,050	1,000
12	.....	4,700	1,550	1,160	2,700	1,250	1,050	1,000
13	.....	3,500	1,430	1,160	5,500	1,550	1,820	1,050
14	.....	1,670	1,430	1,970	3,100	1,670	1,430	1,050
15	.....	1,250	1,430	2,300	1,970	1,550	1,340	1,000
16	1,550	1,670	1,550	1,820	2,300	1,430	1,250	1,100
17	1,160	1,670	1,550	2,300	3,900	1,430	1,100	1,100
18	1,160	1,670	1,430	1,820	1,670	1,430	1,050	845
19	1,250	1,970	1,430	1,550	1,970	1,340	1,050	870
20	1,820	1,670	1,430	1,550	1,430	1,250	1,000	890
21	2,300	2,300	1,340	1,340	1,250	1,160	1,000	930
22	1,550	1,550	1,670	1,250	1,250	1,160	1,000	.....
23	1,550	4,700	1,430	1,250	1,250	1,250	1,000	.....
24	1,670	4,300	1,970	1,250	1,250	1,250	1,000	.....
25	1,670	3,500	4,950	1,160	1,160	1,160	1,050	.....

Mean daily discharge, in second-feet, of Middle Loup River at St. Paul, 1895–1903—Con.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1903.								
26	1,670	3,900	2,700	1,100	10,500	1,160	1,050	.....
27	1,430	4,700	2,300	1,100	11,500	1,250	1,100	.....
28	1,550	2,700	1,820	1,100	9,100	1,160	1,000	.....
29	3,150	5,600	1,820	1,340	5,900	1,250	1,000	.....
30	2,300	12,400	1,820	2,300	3,500	1,250	1,050	.....
31	.....	7,200	.....	1,970	1,550	.....	1,050	.....

Estimated monthly discharge of Middle Loup River at St. Paul, 1895–1903.

[Drainage area, 6,850 square miles.]

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
April.								
1896	2,430	900	1,364	81,200	0.199	0.22	4	6.18
1897	3,600	1,330	2,000	119,000	.291	.32	7	4.89
1899[a]	1,370	856	1,019	60,600	.....	.....	.....	1.12
1903[b]	3,150	1,160	1,719	51,100	.....	.....	.....	1.48
May.								
1895	1,670	933	1,173	72,200	.171	.20	8	2.48
1896	1,440	870	1,154	71,000	.168	.19	6	3.12
1897	1,490	1,055	1,274	78,300	.195	.22	26	.83
1899	1,520	706	1,036	63,700	.150	.17	8	2.10
1903	12,400	1,250	3,209	197,300	.469	.54	7	7.41
June.								
1895	3,960	820	1,396	83,100	.204	.23	5	4.76
1896	2,250	1,220	1,542	88,700	.225	.24	5	4.77
1897	2,600	860	1,037	61,700	.151	.17	3	5.36
1899	14,000	547	1,444	85,900	.210	.23	4	5.57
1903	4,950	1,340	1,938	115,300	.283	.32	11	2.77
July.								
1895	1,100	614	861	52,900	.126	.14	14	.98
1896	1,770	960	1,271	78,100	.186	.21	6	3.43
1897	1,800	660	865	53,200	.130	.15	9	1.65
1899	1,920	780	1,007	61,900	.147	.16	5	3.31
1903	12,000	1,100	2,028	124,700	.296	.34	4	7.68
August.								
1895	1,340	614	973	59,800	.142	.16	6	2.49
1896	1,680	722	975	59,900	.142	.16	17	.92
1897	885	605	673	41,400	.098	.12	3	3.86
1899	2,130	964	1,207	74,200	.176	.21	7	3.16
1903	11,500	1,000	3,365	206,900	.491	.57	8	6.80
September.								
1895	1,950	614	877	52,200	.128	.14	8	1.81
1896	1,190	782	993	59,100	.145	.17	7	2.47
1897	855	585	675	40,200	.099	.11	7	1.51
1899	1,110	938	1,019	60,600	.148	.17	25	.69
1903	1,670	1,160	1,330	79,100	.194	.22	37	.60
October.								
1895	1,220	645	840	51,600	.123	.14	70	.20
1896	1,480	880	1,041	64,000	.152	.18	11	1.56
1897	2,800	705	1,169	71,900	.170	.20	5	4.40
1899	1,190	958	1,109	68,200	.162	.18	47	.38
1903	1,820	1,000	1,234	75,900	.180	.21	17	1.26

[a] April 18 to 30.

[b] April 16 to 30.

ELKHORN RIVER DRAINAGE BASIN.

DESCRIPTION OF BASIN.

Elkhorn River has its source in the sand hills of north-central Nebraska, flows southward, and debouches into Platte River near the Douglas-Sarpy county line. Its drainage area is comparatively broad and comprises over 6,000 square miles. The stream has little fall and meanders back and forth through its alluvial plain, traveling nearly 300 miles before it reaches the Platte.

Over almost its entire drainage area the surface formation consists of yellow clays and fine sandy loam—the loess—although its headwaters drain large tracts of sand hills. The soil throughout is very fertile and the valley has become famous for its production of hay. The annual precipitation, 70 per cent of which falls during the growing months, varies from 20 to 30 inches. Evaporation amounts to 4½ feet annually. Irrigation is practiced to some extent along the upper portions of the stream, a number of ditches being in operation, although abundant crops of hay and grain depending entirely on rainfall are raised on the rolling border lands. The middle and lower portions of the valley are found to be particularly favorable for the production of sugar beets.

The principal tributaries are the North Fork of the Elkhorn, joining the main stream at Norfolk, where a mill is operated by water power, and Logan Creek, draining the northeastern part of the State. Records of daily flow have been obtained at stations located at Norfolk, in Madison County, and at Arlington, in Washington County.

ELKHORN RIVER NEAR NORFOLK.

The station established July 16, 1896, near Norfolk was discontinued November 21, 1903. It was located at the Thirteenth Street Bridge, 2 miles south of Norfolk, in sec. 33, T. 24 N., R. 1 W.

Measurements were made from the highway bridge one-fourth mile above the gage. The results were not altogether satisfactory because the channel being composed of sand and silt changed with every freshet. No attempt was made to obtain records of winter flow, and it is doubtful if such records could have been made with any degree of success.

The gage was an inclined staff on the left bank about one-fourth mile downstream from the highway bridge and was referred to a standard United States Geological Survey bench mark 35 feet west of the gage.

Discharge measurements of Elkhorn River near Norfolk, 1896–1903.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*
1896.			
July 16	O. V. P. Stout	0.98	191
August 27	do	.89	175
September 12	do	.86	176
1897.			
March 24	do	2.72	1,323
May 6	Adna Dobson	2.02	647
May 24	do	1.38	387
June 21	O. V. P. Stout	1.03	270
July 9	do	.90	212
July 30	do	.78	200
August 16	do	.89	220
September 2	do	.68	163
October 15	Adna Dobson	.79	168
1898.			
April 24	Glenn E. Smith	1.60	451
May 12	do	1.84	493
May 23	do	2.06	782
June 10	do	2.86	1,319
June 20	O. V. P. Stout	2.46	760
July 28	Glenn E. Smith	1.05	228
August 20	do	1.28	288
September 10	do	1.00	175
September 29	do	1.00	205
October 22	do	1.34	256
October 28	do	1.40	287
November 16	do	1.40	330
December 16	do		216
December 27	do		217
1899.			
January 26	do		272
April 27	do	1.94	505
May 10	do	2.01	572
May 25	do	2.72	830
July 7	Glenn E. Smith	1.70	427
August 17	do	1.30	274
September 25	do	1.12	184
1900.			
April 20	O. V. P. Stout	2.43	568
May 4	do	3.65	1,207
May 27	do	2.03	463
Do	do	2.03	407
June 29	do	1.38	244
August 3	do	1.23	150
September 12	do	1.66	318
1901.			
March 21	Adna Dobson	2.30	466
May 13	C. B. Channel	2.55	550
June 27	O. V. P. Stout	6.69	3,445
July 31	do	1.36	215
December 30	B. E. Forbes		252
1902.			
March 21	J. C. Stevens	2.39	570
April 13	do	2.22	534
May 12	do	2.16	483
June 16	do	2.54	551
July 3	do	4.36	1,376
July 26	do	2.45	475
August 22	do	1.78	296
September 29	do	5.65	2,497
November 14	do	2.34	502
1903.			
May 25	do	3.97	1,167
June 24	do	3.69	1,193
August 26	do	3.13	784
September 18	E. C. Murphy	2.37	389

Mean daily gage height, in feet, of Elkhorn River near Norfolk, 1896–1903.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1896.						
1		1.80	0.75	0.92	1.34	
2		1.57	.79	.92	1.34	
3		1.29	.77	.94	1.30	
4		1.17	.79	.95	1.30	
5		1.11	.75	.96	1.29	
6		1.05	.75	.95	1.28	
7		1.03	.74	.94	1.28	
8		1.02	.72	1.05	1.27	
9		1.00	.75	1.05	1.25	
10		.98	.84	1.05	2.05	1.90
11		.98	.85	1.05	1.96	
12		.90	.82	1.06	1.92	
13		.91	.84	1.09	1.92	
14		.89	.90	1.06	1.94	
15		.93	.88	1.05	1.97	
16	0.98	.88	.87	1.05	2.12	
17	0.95	0.93	0.90	1.04	2.18	
18	.93	.96	.92	1.05	2.32	
19	.94	.95	.93	1.07	2.11	
20	.89	.94	.94	1.05	1.98	1.55
21	.87	.99	.94	1.05	1.95	
22	.84	.95	.95	1.04	1.95	
23	1.06	.95	.92	1.04	1.96	
24	1.05	.90	.90	1.05	1.98	
25	1.03	.88	.89	1.04	1.98	
26	1.09	.84	.92	1.02	2.00	2.20
27	1.09	.82	.91	1.08	1.98	
28	1.05	.80	.95	1.02	1.96	
29	.99	.79	.95	1.05	1.92	
30	1.03	.80	.92	1.14	1.88	
31	1.36	.78		1.30		

Mean daily gage height, in feet, of Elkhorn River near Norfolk, 1896–1903—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1897.											
1					2.41	1.22	1.21	0.70	0.64	0.63	
2	2.90				2.30	1.33	1.21	.75	.67	.62	
3				4.06	2.22	1.34	1.12	.80	.63	.60	
4				5.95	2.15	1.29	1.08	.81	.61	.61	
5					2.05	1.26	1.02	.81	.62	.61	
6		2.86	3.01	5.66	2.01	1.26	.96	1.00	.58	.64	
7				6.43	1.93	1.24	.95	.91	.57	.64	
8				6.93	1.93	1.20	.89	1.06	.56	.70	
9	2.52			6.62	2.12	1.16	.88	1.06	.50	.67	
10				6.27	1.95	1.16	1.21	1.03	.65	.71	
11				5.50	1.86	1.15	1.36	.97	.65	.72	
12				5.26	1.80	1.12	1.10	.96	.64	.71	
13		2.99		4.90	1.78	1.11	1.02	.90	.64	.85	
14				4.52	1.74	1.11	1.00	.96	.64	.85	
15				4.28	1.73	1.12	.96	.95	.64	.77	
16	2.66			4.08	1.66	1.09	.91	.90	.73	.84	
17				3.99	1.65	1.16	.89	.81	.79	.94	
18				3.98	1.65	1.15	.86	.86	.78	9.71	
19				3.89	1.57		.82	.86	.77	1.02	
20		4.24	3.42	3.93	1.52	1.11	1.01	.81	.70	1.00	
21				3.87	1.48	1.03	1.02	.76	.77	.98	
22				3.72	1.47	1.03		.76	.70	.96	
23	2.04			3.56	1.47	1.04	.91	.76	.70	.94	
24				3.42	1.38	1.03	.90	.74	.76	.91	
25				3.26	1.35	1.00	.86	.75	.70	.94	
26				3.10	1.34	1.01	.86	.72	.69	.96	
27		3.22	2.24	2.94		1.00	.82	.70	.68	.99	
28				2.82	1.31	1.01	.81	.71	.64	1.06	
29				2.65	1.26	1.07	.76	.67	.66	1.07	
30	2.72			2.51	1.24	1.18	.76	.70	.63	1.09	
31					1.22		.76	.64		1.12	
1898.											
1				1.66	1.53	2.64	1.75	1.03	1.08	.93	1.37
2				1.65	1.53	2.53	1.73	1.03	1.00	.99	1.35
3				1.65	1.66	2.40	1.53	1.02	1.00	1.03	1.35
4				1.64	1.67	2.77	1.66	1.02	1.00	1.03	1.35
5				1.63	1.76	4.44	1.67	1.01	.98	1.04	1.35
6				1.63	1.82	4.70	1.66	1.02	.98	1.02	1.35
7				1.57	1.93	3.62	1.67	1.03	.97	1.02	1.35
8				1.58	1.87	3.36	1.71	1.33	.98	1.02	1.36
9				1.56	1.95	3.28	1.68	1.36	1.01	1.03	1.33
10				1.55	1.97	3.78	1.65	1.56	1.05	1.04	1.33
11				1.55	1.90	3.47	1.63	1.60	1.03	1.15	1.34
12				1.59	1.84	3.15	1.57	1.70	1.17	1.17	1.34
13				1.61	1.82	3.00	1.55	1.56	1.18	1.18	1.34
14				1.61	1.87	2.92	1.49	1.56	1.14	1.18	1.39
15				1.60	1.96	2.77	1.45	1.49	1.15	1.19	1.42
16				1.60	1.85	2.67	1.48	1.44	1.13	1.13	1.42
17				1.59	1.86	2.62	1.28	1.42	1.13	1.23	1.43
18				1.61	2.06	2.58	1.26	1.37	1.13	1.28	1.41
19				1.63	2.08	2.52	1.26	1.39	1.19	1.30	1.43
20				1.65	2.68	2.54	1.18	1.42	1.07	1.33	1.50
21				1.64	2.69	2.49	1.10	1.37	1.03	1.30	1.65
22				1.60	2.65	2.34	1.13	1.21	.96	1.32	1.72
23				1.60	2.56	2.25	1.10	1.22	.98	1.33	1.76
24				1.60	2.63	2.15	1.10	1.26	1.02	1.37	1.80
25				1.57	3.23	2.13	1.13	1.27	1.03	1.36	1.80
26				1.53	3.13	2.10	1.03	1.24	1.01	1.36	1.80
27				1.52	3.10	2.04	1.01	1.24	1.12	1.39	1.87
28				1.49	3.02	1.96	1.00	1.24	.97	1.38	1.87
29				1.47	2.99	1.91	.98	1.22	.97	1.38	1.87
30				1.52	2.89	1.85	1.03	1.16	.97	1.37	1.87
31					2.72		1.07	1.15		1.37	
1899.											
1					1.94	2.07	2.45	1.20	.97	1.13	
2					2.24	2.03	2.20	1.23	.97	1.19	
3					2.30	1.93	1.97	1.27	.76	1.23	
4					3.20	1.85	1.66	1.32	.70	1.26	
5					2.41	1.85	1.76	1.33	.67	1.22	

Mean daily gage height, in feet, of Elkhorn River near Norfolk, 1896–1903—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1899.											
6					2.31	1.87	1.74	1.33	1.06	1.23	
7				1.90	2.24	2.45	1.68	1.36	1.08	1.22	
8				1.87	2.16	2.22	1.71	1.35	1.12	1.27	
9				1.90	2.06	1.92	1.67	1.45	1.15	1.28	
10				1.93	2.00	1.82	1.73	1.27	1.13	1.25	
11				2.00	1.92	1.75	1.73	1.28	1.13	1.20	
12				2.01	1.83	1.74	1.78	1.48	1.10	1.20	
13				2.05	1.78	1.64	1.69	1.48	1.06	1.29	
14				2.05	1.73	1.63	1.65	1.33	1.02	1.27	
15				2.03	1.77	1.64	1.56	1.34	1.06	1.33	
16				1.98	1.77	1.65	1.51	1.33	1.11	1.30	
17				1.98	1.74	1.60	1.48	1.38	1.09	1.32	
18				1.97	1.70	1.53	1.45	1.26	1.11	1.31	
19				1.99	1.80	1.57	1.43	1.25	1.04	1.32	
20				1.90	3.50	1.57	1.45	1.23	1.03	1.34	
21				1.97	3.58	1.57	1.38	1.25	1.02	1.33	
22				1.89	3.34	1.53	1.34	1.23	1.03	1.33	
23				1.85	2.63	1.45	1.26	1.17	1.04	1.33	
24				1.84	2.65	1.55	1.21	1.17	1.17	1.31	
25				1.84	2.75	2.07	1.23	1.14	1.11	1.36	
26				1.87	2.80	1.75	1.23	1.13	1.10	1.31	
27				1.93	2.85	2.65	1.24	1.12	1.12	1.34	
28				1.95	2.75	3.75	1.24	.97	1.12	1.34	
29				1.89	2.35	3.40	1.24	.95	1.13	1.31	
30				1.73	2.20	3.02	1.21	.99	1.12	1.32	
31					2.07		1.22	.97		1.30	
1900.											
1				1.89	3.56	2.09	1.34	1.28	1.35	1.32	1.86
2				1.87	3.62	2.15	1.35	1.26	1.30	1.33	1.85
3				1.80	3.62	2.20	1.34	1.24	1.29	1.35	1.82
4				1.78	3.67	2.03	1.30	1.20	1.34	1.34	1.81
5				1.78	3.65	1.99	1.33	1.21	1.35	1.34	1.82
6				1.77	3.67	1.85	1.32	1.16	1.27	1.34	1.81
7				1.76	3.58	1.87	1.23	1.16	1.25	1.36	1.81
8				1.71	3.40	1.80	1.23	1.15	1.25	1.34	1.82
9				1.83	3.24	1.60	1.25	1.14	1.24	1.34	1.82
10				1.87	3.25	1.69	1.22	1.10	1.25	1.35	1.80
11				1.79	2.95	1.99	1.10	1.04	1.55	1.35	1.82
12				1.83	2.84	1.80	1.15	1.13	1.58	1.32	1.75
13				1.80	2.76	1.61	1.13	1.14	1.52	1.31	1.74
14				1.79	2.62	1.60	1.13	1.20	1.49	1.35	1.76
15				1.84	2.59	1.53	1.62	1.30	1.47	1.35	1.76
16				1.97	2.52	1.58	1.62	1.97	1.45	1.34	1.74
17				2.57	2.52	1.57	1.55	1.67	1.42	1.35	1.75
18				2.40	2.37	1.50	1.63	1.65	1.38	1.35	
19				2.39	2.32	1.50	1.62	1.68	1.42	1.34	
20				2.42	2.24	1.50	1.52	1.71	1.46	1.36	
21				2.42	2.17	1.57	1.52	1.62	1.46	1.62	
22				2.48	2.13	1.57	1.52	1.52	1.38	1.75	
23				2.66	2.11	1.49	1.53	1.48	1.42	1.97	
24				2.99	1.95	1.47	1.53	1.39	1.41	1.85	
25				3.02	1.95	1.45	1.52	1.42	1.42	1.85	
26				3.10	2.02	1.39	1.39	1.48	1.35	1.83	
27				3.31	1.96	1.34	1.41	1.53	1.33	1.86	
28				3.48	1.93	1.34	1.39	1.53	1.35	1.85	
29				3.68	1.83	1.36	1.42	1.46	1.35	1.85	
30				3.54	1.86	1.35	1.34	1.42	1.33	1.90	
31					1.85		1.30	1.35		1.91	
1901.											
1				2.22	2.74	1.65	5.03	1.42	.90	1.81	1.81
2				2.25	2.72	1.60	4.82	1.31	.89	1.80	1.80
3				2.28	2.69	1.60	4.45	1.29	.89	1.77	1.82
4				2.34	2.46	1.75	4.00	1.24	.87	1.76	1.84
5				2.36	2.30	1.71	4.42	1.23	.87	1.75	1.85
6				2.34	2.44	1.60	4.32	1.20	.85	1.75	1.87
7				2.34	3.24	1.63	4.11	1.17	.85	1.75	1.88
8				2.34	3.03	1.67	3.95	1.15	.92	1.76	1.93
9				2.35	3.04	1.65	3.85	1.14	1.05	1.76	1.95
10				2.36	2.84	1.85	3.65	1.12	1.06	1.76	1.93

Mean daily gage height, in feet, of Elkhorn River near Norfolk, 1896–1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1901.											
11				2.37	2.73	1.76	3.42	1.10	1.25	1.75	1 92
12				2.42	2.64	1.80	3.05	1.03	1.53	1.76	1.90
13				2.46	2.55	1.85	2.79	1.00	1.83	1.78	1.87
14				2.64	2.63	2.05	2.65	.99	1.92	1.81	1.85
15				2.62	2.29	2.18	2.53	.95	1.97	1.83	1.85
16				2.74	2.29	3.06	2.40	.94	1.96	1.85	1.85
17				2.94	2.25	3.24	2.33	.89	1.85	1.85	1.87
18				3.04	2.20	3.42	2.14	1.14	1.81	1.85	1.87
19				3.04	2.20	4.05	1.95	1.12	1.80	1.86	1.87
20				3.06	2.11	4.80	1.90	1.10	1.88	1.87	1.87
21				3.06	2.02	5.18	1.90	1.00	1.87	1.87	1.88
22				3.27	2.00	5.02	1.85	.96	1.86	1.87	1.88
23				3.33	1.95	5.40	1.83	.95	1.85	1.87	1.90
24				3.23	1.85	5.62	1.80	.93	1.83	1.89	1.83
25				2.22	1.90	6.17	1.73	.92	1.82	1.87	1.83
26				3.22	1.85	6.53	1.70	.95	1.81	1.8	1.85
27				3.16	1.85	6.67	1.65	.97	1.83	1.8	1.85
28				3.16	1.85	6.67	1.62	.99	1.84	1.8	1.81
29				2.99	1.85	6.00	1.60	.95	.....	1.8	1.81
30				2.84	1.80	5.70	1.54	.92	.....	1.81	1.81
31				.....	1.75	.....	1.52	.91	.....	.....	.....
1902.											
1				2.95	2.55	2.50	1.90	1.90	2.35	5.92	2.88
2				3.25	2.60	2.35	3.11	1.90	2.70	5.76	2.71
3				3.45	2.60	2.20	4.48	1.85	2.50	5.52	2.69
4				3.20	2.55	2.10	4.00	1.85	2.40	5.35	2.65
5				3.20	2.55	2.95	3.55	1.83	2.10	4.73	2.65
6				2.97	2.50	3.07	3.05	1.81	1.90	4.60	2.59
7				2.90	2.50	2.50	2.90	1.80	1.95	4.39	2.58
8				2.85	2.45	2.55	2.72	1.79	1.97	4.26	2.58
9				2.80	2.40	2.50	2.80	1.77	1.95	4.17	2.47
10			2.55	2.70	2.30	2.40	2.85	1.75	1.99	4.06	2.47
11			2.60	2.50	2.25	2.35	2.85	1.75	2.00	4.01	2.43
12			2.62	2.32	2.20	2.20	2.90	1.73	2.01	4.26	2.30
13			2.75	2.20	2.20	2.10	2.90	1.70	2.00	4.10	2.21
14			2.72	2.15	2.15	2.40	3.40	1.68	1.98	3.88	2.10
15			2.72	2.15	2.10	2.40	4.00	1.65	1.93	3.66	2.15
16				2.12	2.15	2.70	3.85	1.70	1.90	3.41	2.03
17				2.13	2.20	2.80	3.55	1.70	1.85	3.01	1.99
18				2.15	2.30	2.75	3.85	1.73	1.85	2.97	1.97
19				2.13	2.60	2.70	3.00	1.75	1.84	3.72	1.97
20			2.65	2.10	2.80	2.61	3.40	1.75	2.00	3.65	2.03
21			2.52	2.15	2.85	2.50	3.25	1.78	2.35	3.49	2.03
22			2.45	2.10	2.80	2.30	3.05	1.80	2.45	3.42	2.09
23			2.42	2.10	2.75	2.22	2.90	1.85	2.37	3.39	2.13
24			2.38	2.01	2.75	2.12	2.85	2.00	2.65	3.29	1.12
25			2.40	2.00	2.70	1.95	2.60	2.63	2.83	3.22	1.22
26			2.40	2.20	2.60	1.85	2.49	2.78	3.10	3.16	1.26
27			2.40	2.35	2.61	1.82	2.40	2.90	3.47	3.06	.....
28			2.45	2.35	2.61	1.80	2.00	3.00	4.89	2.96	.....
29			2.38	2.45	2.60	1.75	2.19	2.60	5.69	2 95	.....
30			2.35	2.50	2.55	1.75	2.10	2.10	5.94	2.91	.....
31			2.30	.....	2.55	.....	2.00	2.10	.....	2.82	.....
1903.											
1				4.40	3.54	6.69	3.32	3.52	3.61	1.60	1.33
2				4.26	3.81	6.46	3.01	3.67	3.53	2.03	1.37
3				4.21	3.73	6.94	3.33	3.85	3.42	2.17	1.49
4				4.12	3.65	6.76	7.80	3.87	3.30	2.09	1.57
5				4.01	3.61	7.22	6.33	3.65	3.23	2.04	1.89
6				3.97	3.52	7.15	4.21	3.76	3.25	2.17	1.72
7				3.84	3.31	6.98	3.84	3.75	3.14	3.19	1.64
8				3.78	3.32	6.49	3.32	3.64	3.01	2.61	1.51
9			7.00	3.63	3.30	6.26	3.16	3.58	2.97	2.15	1.43
10			8.30	3.60	5.66	5.89	2.81	3.45	2.91	1.91	1.36
11			7.50	3.54	5.11	5.58	2.63	3.65	2 85	1.43	1.29
12			5.30	3.51	5.08	5.18	2.21	3.85	2.98	1.62	1.30
13			4.54	3.42	4.38	4.88	2.32	3.90	3.01	1.73	1.30
14			5.00	3.31	3.95	4.53	2.51	4.02	3.00	1.64	1.29
15			5.88	3.20	3.97	4.21	2.37	4.33	2.96	1.51	1.27

Mean daily gage height, in feet, of Elkhorn River near Norfolk, 1896–1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1903.											
16			6.80	3.17	4.07	4.05	2.43	3.97	2.84	1.56	1.23
17			7.95	3.11	4.31	3.84	4.45	3.87	2.62	1.49	
18			7.75	3.04	4.01	3.62	3.71	3.72	2.42	1.47	
19			6.12	2.94	3.85	3.42	3.57	3.75	2.38	1.47	
20			5.87	2.91	3.77	3.21	3.21	3.80	2.27	1.47	
21			5.85	2.81	3.61	4.92	2.95	3.91	2.18	1.43	1.33
22			5.82	2.71	3.61	4.43	2.86	3.63	2.16	1.41	
23			5.80	2.63	3.73	4.21	2.73	3.54	2.15	1.39	
24			5.86	2.59	3.95	3.51	2.65	3.43	2.15	1.35	
25			5.71	2.55	3.97	3.33	2.54	3.43	2.13	1.31	
26			5.54	2.45	3.97	3.20	2.61	3.62	2.10	1.29	
27			5.29	2.42	4.50	3.03	2.72	3.83	1.98	1.36	
28			5.09	2.65	4.43	3.00	2.83	5.00	1.85	1.34	
29			4.97	3.15	6.55	2.94	2.89	4.38	1.78	1.37	
30			4.76	3.35	9.25	2.83	2.97	4.13	1.61	1.33	
31			4.50		7.68		2.99	3.94		1.30	

Mean daily discharge, in second-feet, of Elkhorn River near Norfolk, 1896–1903.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Day.	July.	Aug.	Sept.	Oct.	Nov.
1896.						1896.					
1		570	158	182	313	17	186	183	179	210	
2		409	163	182	313	18	184	188	192	213	
3		294	161	185	298	19	185	186	183	220	
4		253	163	186	298	20	178	185	185	213	
5		233	158	188		21	174	193	185	213	
6		213	158	186		22	175	186	186	210	
7		206	157	185		23	216	186	182	210	
8		203	155	213		24	225	179	179	213	
9		197	158	213		25	206	176	178	210	
10		191	170	213		26	226	170	182	203	
11		191	172	213		27	226	167	180	223	
12		179	167	216		28	213	165	186	203	
13		180	170	226		29	194	163	186	213	
14		177	178	216		30	206	165	182	243	
15		186	176	213		31	321	162		298	
16	191	176	174	213							

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Day.	May.	June.	July.	Aug.	Sept.	Oct.
1897.							1897.						
1	940	330	320	165	150	145	17	500	310	220	195	190	235
2	840	370	325	180	160	145	18	500	305	210	210	190	245
3	780	370	290	195	150	140	19	460	310	200	210	185	260
4	740	355	285	215	160	140	20	440	275	260	195	170	255
5	680	340	260	215	145	140	21	430	265	260	180	185	250
6	660	340	240	255	135	140	22	420	265	230	180	170	240
7	620	340	240	230	130	150	23	420	270	230	180	170	235
8	620	320	220	275	130	170	24	390	265	225	180	180	230
9	720	310	220	275	115	160	25	385	255	210	180	170	235
10	630	310	325	265	155	170	26	370	260	210	170	165	240
11	590	305	380	245	155	170	27	370	255	200	170	160	250
12	560	290	290	240	150	170	28	350	280	195	170	150	275
13	560	290	260	225	150	210	29	340	280	180	160	155	280
14	540	290	255	240	150	210	30	320	320	180	170	145	285
15	530	290	240	240	150	185	31	330		180	150		295
16	500	285	230	225	175	205							

72607—IRR 230—09——10

Mean daily discharge, in second-feet, of Elkhorn River near Norfolk, 1896–1903—Con.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1898.									
1		500	410	860	435	215	195	185	
2		495	405	800	430	215	175	200	
3		495	460	730	350	210	170	185	
4		490	460	1,060	400	210	170	210	
5		490	490		405	210	165	210	
6		490	515		405	210	165	210	
7		465	565		410	215	160	200	
8		470	550		430	310	165	195	
9		460	565		420	320	175	200	
10		455	565		405	390	185	200	
11		455	530		400	400	175	235	
12		473	490		380	440	210	245	
13		480	480		370	385	220	240	
14		480	490	1,380	350	380	210	235	
15		480	560	1,140	340	360	215	235	
16		480	455	1,000	350	340	210	210	
17		473	455	930	285	330	215	240	
18		480	530	870	280	310	220		
19		485	525	805	280	320	235		
20		490	840	810	255	325	175	260	
21		480	830	780	235	305	195	250	
22		460	790	690	210	250	175	250	
23		455	730	640	235	220	245	255	
24		450	760	585	240	260	200	270	
25		440	1,470	585	245	265	210	265	
26		425	1,320	580	215	250	220	265	
27		415	1,300	550	210	250	240	280	
28		405	1,170	520	210	250	195	275	
29		399	1,160	500	200	245	195	275	
30		410	1,045	475	215	220	195		
31			895		230	220			
1899.									
1			515	469	820	243	158	180	
2			660	456	633	253	158	197	
3			562	419	532	266	105	206	
4			700	392	408	282	90	215	
5			788	392	448	286	80	203	
6			788	404	439	286	180	206	
7		490	694	660	419	296	186	203	
8		477	647	553	431	292	194	218	
9		490	594	431	416	327	203	221	
10		502	567	396	430	266	194	209	
11		532	528	370	439	266	194	194	
12		536	480	370	460	334	186	194	
13		553	460	334	423	334	174	221	
14		553	431	334	408	282	161	215	
15		545	435	340	370	286	171	234	
16		523	423	347	352	282	186	221	
17		523	404	334	341	299	177	227	
18		519	374	309	330	259	183	224	
19		528	400	326	323	256	163	227	
20		490	1,700	330	330	250	161	234	
21		519	1,750	334	306	256	156	227	
22		477	1,500	323	292	246	159	227	
23		469	772	296	266	227	161	227	
24		464	780	334	250	224	197	221	
25		464	868	545	256	212	180	237	
26		477	905	416	256	209	174	221	
27		502	953	972	259	206	180	227	
28		515	858	2,200	259	161	177	227	
29		490	580	1,900	259	156	180	218	
30		427	519	1,400	246	166	177	221	
31			464		250	163		215	
1900.									
1		390	1,180	465	225	167	210	198	380
2		380	1,210	492	230	160	195	200	375
3		432	1,190	513	225	153	190	210	365
4		343	1,210	445	213	143	204	205	362
5		343	1,200	428	220	145	213	205	365

Mean daily discharge, in second-feet, of Elkhorn River near Norfolk, 1896–1903—Con.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1900.									
6	.....	340	1,280	370	215	135	190	205	362
7	.....	330	1,150	383	188	135	185	213	362
8	.....	318	2,400	358	188	130	185	205	365
9	.....	352	830	290	190	127	180	205	365
10	.....	367	840	320	180	117	185	210	360
11	.....	340	670	430	145	110	280	210	365
12	.....	350	624	358	160	127	290	198	340
13	.....	340	600	290	153	130	264	195	337
14	.....	330	545	290	150	150	250	210	343
15	.....	346	545	265	294	177	247	210	343
16	.....	390	526	283	294	400	238	205	337
17	.....	648	545	280	304	290	230	210	340
18	.....	565	490	257	294	283	220	210	.....
19	.....	560	485	257	290	293	230	205	.....
20	.....	568	465	257	256	310	242	213	.....
21	.....	563	445	280	250	280	242	292	.....
22	.....	580	440	283	250	248	220	340	.....
23	.....	650	440	257	250	204	230	425	.....
24	.....	840	380	250	250	214	228	375	.....
25	.....	850	385	246	248	220	230	375	.....
26	.....	910	383	230	177	240	210	368	.....
27	.....	1,080	400	220	210	260	200	380	.....
28	.....	1,280	395	223	200	260	210	375	.....
29	.....	1,570	360	230	210	240	210	375	.....
30	.....	1,210	370	230	285	230	200	395	.....
31	.....	.....	367	.....	173	204	.....	400	.....
1901.									
1	.....	431	640	282	2,003	231	150	322	322
2	.....	441	630	270	1,857	211	149	319	319
3	.....	452	617	270	1,608	207	149	312	324
4	.....	471	516	307	1,324	199	147	310	329
5	.....	479	457	297	1,590	197	147	308	332
6	.....	471	508	270	1,517	192	142	308	337
7	.....	471	881	277	1,390	187	142	308	339
8	.....	471	765	287	1,294	184	152	310	352
9	.....	475	767	282	1,235	182	169	310	357
10	.....	479	687	332	1,058	179	170	310	352
11	.....	482	635	309	983	176	201	308	349
12	.....	501	593	319	787	166	254	310	344
13	.....	516	550	332	663	162	327	315	337
14	.....	593	589	384	598	161	349	322	332
15	.....	584	454	419	544	156	362	326	332
16	.....	640	454	777	493	155	360	332	332
17	.....	729	441	881	468	149	332	332	337
18	.....	782	425	983	404	182	322	332	337
19	.....	782	425	1,383	357	179	319	334	337
20	.....	792	399	1,879	344	176	339	337	337
21	.....	792	375	2,164	344	162	337	337	339
22	.....	901	370	1,991	332	157	334	337	339
23	.....	933	357	2,300	326	156	332	337	344
24	.....	880	332	2,503	319	154	326	342	327
25	.....	875	344	2,997	302	152	324	337	327
26	.....	875	332	3,330	294	156	322	332	332
27	.....	841	332	3,435	282	158	326	326	332
28	.....	841	332	3,438	275	161	328	324	322
29	.....	758	332	2,831	270	156	332	322	322
30	.....	687	319	2,567	256	152	326	322	322
31	.....	.....	306	.....	215	151	.....	322	.....
1902.									
1	.....	855	663	580	287	321	454	2,408	701
2	.....	1,022	687	516	691	321	593	2,597	621
3	.....	1,028	687	457	1,462	309	548	2,381	616
4	.....	999	659	425	1,170	309	508	2,232	598
5	.....	999	668	782	909	304	381	1,787	598
6	.....	876	635	840	673	299	329	1,684	571
7	.....	840	630	566	607	299	341	1,544	566
8	.....	821	607	584	531	296	349	1,462	566
9	.....	797	584	557	571	292	344	1,408	520
10	553	749	540	512	598	287	354	1,342	520

Mean daily discharge, in second-feet, of Elkhorn River near Norfolk, 1896–1903—Con.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.									
11	575	659	516	489	593	287	357	1,312	504
12	584	575	497	435	630	282	360	1,462	457
13	644	527	497	403	635	272	357	1,384	428
14	630	508	475	497	882	270	352	1,234	397
15	630	508	457	497	1,234	263	341	1,105	411
16	.....	497	471	621	1,146	277	334	965	378
17	.....	497	489	663	977	277	321	758	367
18	.....	504	523	635	977	284	321	739	362
19	.....	497	659	603	701	290	319	1,146	362
20	598	482	749	557	954	290	360	1,105	378
21	630	501	773	504	825	296	461	1,011	378
22	598	482	744	438	729	301	497	971	394
23	584	479	720	438	653	314	471	954	405
24	571	447	715	378	640	352	589	898	.....
25	580	444	691	329	531	557	668	860	.....
26	580	516	640	301	489	626	797	830	.....
27	584	570	644	290	457	682	994	782	.....
28	607	570	640	282	344	729	1,886	734	.....
29	580	621	635	265	394	544	2,534	729	.....
30	566	644	607	259	370	378	2,750	710	.....
31	544	.....	607	.....	344	378	.....	668	.....
1903.									
1	.....	1,500	940	3,320	960	1,020	1,010	210	180
2	.....	1,420	1,090	3,120	800	1,100	960	300	190
3	.....	1,390	1,050	3,560	960	1,210	890	340	230
4	.....	1,340	1,000	3,410	5,000	1,220	825	320	240
5	.....	1,270	980	3,840	3,190	1,090	790	300	320
6	.....	1,250	930	3,860	1,480	1,150	790	340	280
7	.....	1,170	820	3,740	1,260	1,150	730	710	260
8	.....	1,080	820	3,200	950	1,080	670	460	230
9	3,680	990	810	3,000	860	1,050	640	330	210
10	4,500	970	2,350	2,680	690	960	610	270	200
11	4,000	940	1,920	2,410	610	1,080	580	180	190
12	2,140	920	1,710	2,080	440	1,200	640	210	190
13	1,600	870	1,430	1,870	480	1,230	640	230	190
14	1,920	820	1,180	1,640	550	1,290	640	240	190
15	2,640	760	1,190	1,440	490	1,480	610	190	190
16	3,470	750	1,250	1,350	510	1,260	550	200	180
17	4,200	720	1,390	1,230	1,620	1,200	460	210	.....
18	4,100	690	1,210	1,100	1,160	1,110	400	200	.....
19	2,850	640	1,120	990	1,070	1,130	390	200	.....
20	2,630	630	1,070	890	870	1,160	360	200	.....
21	2,620	580	990	1,970	740	1,220	340	200	200
22	2,590	540	980	1,640	700	1,060	330	190	.....
23	2,570	500	1,050	1,500	640	1,000	330	190	.....
24	2,620	490	1,180	1,090	600	940	330	180	.....
25	2,490	480	1,170	980	540	940	330	180	.....
26	2,340	440	1,160	910	580	1,050	320	180	.....
27	2,130	430	1,500	820	630	1,170	290	190	.....
28	1,980	510	1,460	800	670	1,920	260	180	.....
29	1,890	740	3,160	770	700	1,490	240	190	.....
30	1,740	840	8,000	720	740	1,330	210	180	.....
31	1,570	.....	5,000	.....	740	1,210	.....	180	.....

Estimated monthly discharge of Elkhorn River near Norfolk, 1896–1903.

[Drainage area, 2,470 square miles.]

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
March.								
1902 [a]	640	540	591	21,100				1.37
1903 [b]	4,500	1,570	2,707	123,500				1.25
April.								
1898	500	399	464	27,600	0.198	0.21	13	1.59
1899 [c]	553	427	503	29,900				1.01
1900	1,570	318	586	34,900	.237	.27	5	5.21
1901	933	431	648	38,600	.261	.29	14	2.06
1902	1,030	444	651	38,700	.263	.29	16	1.86
1903	1,500	430	856	50,900	.345	.39	17	2.35
May.								
1897	940	320	539	33,100	.218	.23	22	1.17
1898	1,470	405	704	43,300	.284	.33	7	4.97
1899	1,750	374	745	45,800	.301	.35	6	5.72
1900	2,400	360	721	44,300	.291	.33	11	3.05
1901	881	306	489	30,100	.197	.23	9	2.46
1902	773	471	616	37,900	.248	.29	11	2.71
1903	8,000	810	1,610	99,000	.610	.75	10	7.22
June.								
1897	370	255	302	18,000	.122	.14	4	3.65
1898		475	1,000	59,500	.404	.45	10	4.56
1899	2,200	296	550	32,700	.222	.24	5	4.67
1900	513	220	316	18,800	.128	.15	7	2.10
1901	3,440	270	1,271	75,600	.513	.57	7	8.37
1902	840	259	490	29,200	.198	.22	4	5.51
1903	3,860	720	1,998	118,900	.809	.90	31	2.88
July.								
1896 [d]	321	172	206	6,500				5.22
1897	380	180	244	15,000	.098	.12	4	2.74
1898	435	200	317	19,500	.128	.15	6	2.54
1899	820	246	376	23,100	.152	.17	6	2.66
1900	304	145	223	13,700	.090	.10	2	4.62
1901	2,000	215	765	47,000	.309	.35	60	.58
1902	1,460	287	710	43,600	.286	.33	5	6.61
1903	5,000	440	1,007	61,900	.406	.47	7	6.50
August.								
1896	570	162	210	12,900	.085	.10	8	1.25
1897	275	150	206	12,700	.083	.09	3	2.77
1898	440	210	285	17,500	.115	.14	6	2.42
1899	334	156	254	15,600	.103	.12	4	3.06
1900	400	110	203	12,500	.082	.09	2	3.53
1901	231	149	172	10,600	.070	.08	8	.96
1902	729	263	354	21,800	.143	.16	4	4.57
1903	1,920	940	1,177	72,400	.475	.55	10	5.52
September.								
1896	186	155	173	10,300	.070	.08	3	2.47
1897	190	115	158	9,400	.064	.07	3	2.09
1898	245	160	195	11,600	.079	.09	7	1.23
1899	203	80	168	10,000	.068	.08	8	1.04
1900	290	180	220	13,100	.089	.10	3	3.29
1901	362	142	269	16,000	.109	.12	2	7.62
1902	2,750	319	642	38,200	.260	.29	6	4.75
1903	1,010	210	539	32,100	.218	.24	21	1.14
October.								
1896	298	182	210	12,900	.085	.10	4	2.24
1897	295	140	209	12,800	.084	.09	3	3.04
1898	280	185	236	14,500	.095	.12	11	1.09
1899	237	180	217	13,300	.088	.10	14	.72
1900	425	195	265	16,300	.107	.13	4	3.12
1901	342	308	323	19,900	.130	.15	7	2.05
1902	2,600	668	1,265	77,800	.510	.59	7	.81
1903	710	180	248	15,200	.101	.12	7	1.80
November.								
1898 [e]	335	285	303	18,000				.35
1900 [f]	380	337	357	21,200				.19
1901	357	319	332	19,700	.134	.15	14	1.07
1902 [g]	701	362	482	22,000				.18
1903 [h]	320	180	229	7,300				1.09

[a] 18 days in March.
[b] March 9 to 31.
[c] April 7 to 30.
[d] July 16 to 31.
[e] November 1 to 19.
[f] November 1 to 17.
[g] November 1 to 23.
[h] November 1 to 16.

ELKHORN RIVER AT ARLINGTON.

The station at Arlington was established April 28, 1899, and discontinued November 21, 1903. It was located at the highway bridge 1 mile south of Arlington, in sec. 13, T. 17 N., R. 9 E., just below the Chicago and Northwestern Railway bridge. The location is shown on the Fremont topographic atlas sheet.

Results of measurements at this station are fairly satisfactory, although in times of flood the current was oblique to the bridge and eddies formed which resulted in a silting up of the channel. Observations of winter flow were not attempted, although such efforts would no doubt have been fairly successful.

The original inclined gage was located 200 feet downstream from the highway bridge, on the right bank. This rod was washed out on May 10, 1899, and on May 29 of the same year a similar gage was installed 25 feet farther upstream; the datum was not changed. This gage, which was used until the close of the season of 1903, was referred to two bench marks, as follows: (1) A spike in a pile 150 feet downstream from the bridge on the right bank; elevation, 6.36 feet above the zero of the gage. (2) A spike in a piling 140 feet downstream from the gage on the right bank and 20 feet from the water's edge; elevation, 9.12 feet above the zero of the gage.

Discharge measurements of Elkhorn River at Arlington, 1899–1903.

Date.	Hydrographer.	Gage height.	Discharge.
1899.		*Feet.*	*Sec.-ft.*
February 4	Glenn E. Smith		3,370
February 17	do		269
April 28	do	1.78	794
May 9	do	3.90	1,779
May 24	do		1,626
May 29	do	4.24	2,462
June 22	do	2.70	1,199
July 8	do	2.23	1,016
August 9	do	1.72	732
August 18	do	1.40	606
September 15	do	.82	344
September 24	do	.75	340
October 13	do	.90	351
1900.			
April 19	O. V. P. Stout	2.06	685
May 5	do	3.25	1,411
Do	do	3.25	1,458
June 1	do	1.80	723
Do	do	1.80	693
June 28	do	1.25	465
Do	do	1.25	468
August 2	do	1.26	431
Do	do	1.26	452
August 14	do	1.16	415
Do	do	1.16	441
September 12	do	4.74	2,855
November 14	Glenn E. Smith	2.05	838
November 14	do	2.05	760
1901.		*Feet.*	*Sec.-ft.*
June 24	O. V. P. Stout	6.76	3,989
July 12	do	2.99	1,331
July 30	do	1.15	564
November 9	Frank Dobson	1.90	706
June 17	O. V. P. Stout	2.37	905
1902.			
March 19	B. E. Forbes	1.85	771
April 14	J. C. Stevens	2.15	924
June 17	do	1.85	743
July 7	do	6.29	4,363
July 29	do	3.57	1,402
August 22	do	3.75	1,388
September 10	do	2.10	805
October 4	do	4.79	2,676
1903.			
April 10	do	4.40	2,120
May 15	do	7.36	4,330
June 3	do	10.30	8,431
June 22	do	5.40	2,136
July 15	do	4.65	2,093
August 29	do	10.65	8,658
September 16	do	7.70	4,883

Mean daily gage height, in feet, of Elkhorn River at Arlington, 1899–1903.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1899.										
1			1.84	3.81	2.68	1.32	0.87	0.68		
2			2.07	3.65	2.68	1.25	.89	.69		
3			1.86	3.63	3.19	1.17	.76	.68		
4			1.96	3.50	2.97	1.36	.73	.67		
5			2.30	3.41	2.81	1.50	.70	.68		
6			3.00	3.42	2.66	1.40	.72	.73		
7			4.37	3.54	2.38	1.56	.74	.74		
8			3.96	2.87	2.23	2.00	.75	.78		
9			3.91	2.58	2.23	1.70	.74	.79		
10				2.38	2.12	1.57	.79	.82		
11				2.35	2.13	1.66	.80	.86		
12				2.40	2.02	1.40	.82	.88		
13				5.35	2.10	1.41	.81	.90		
14				4.94	1.94	1.35	.84	.92		
15				4.55	1.86	1.42	.79	.93		
16				4.12	1.83	1.49	.75	.94		
17				4.30	1.76	1.48	.74	.92		
18				4.48	1.68	1.39	.73	.91		
19				3.67	1.64	1.27	.73	.92		
20				3.16	1.63	1.24	.65	.96		
21				2.67	1.57	1.09	.66	.98		
22				2.76	1.50	1.10	.69	1.02		
23				2.75	1.55	1.09	.72	1.04		
24				2.65	1.36	1.21	.75	1.10		
25				2.51	1.30	1.23	.76	1.12		
26				2.21	1.27	1.03	.70	1.11		
27				2.32	1.27	1.02	.69	1.12		
28		1.78		2.19	1.25	1.07	.66	1.13		
29		1.76	4.24	2.32	1.26	1.03	.64	1.12		
30		1.81	4.15	2.64	1.20	1.01	.65	1.13		
31			4.17		1.22	.85		1.11		
1900.										
1		1.76	3.59	1.81	.97	1.37	2.14	1.94	3.82	
2		1.75	3.51	1.87	.95	1.24	1.75	1.84	3.88	
3		1.76	3.40	1.75	.98	1.16	1.52	1.82	3.75	
4		1.74	3.33	1.93	.96	1.08	1.38	1.74	3.60	
5		1.67	3.24	1.88	1.18	1.06	1.31	1.70	3.40	
6		1.65	3.18	1.90	1.09	.99	1.27	1.65	3.15	
7		1.61	3.22	1.92	1.02	.93	1.25	1.60	2.80	
8		1.60	3.35	1.81	.99	.88	1.23	1.56	2.63	
9		1.56	3.56	1.68	.92	.82	1.25	1.53	2.39	
10		1.59	4.18	1.66	.88	.78	1.16	1.49	2.26	
11		1.57	4.00	1.62	.91	.80	1.54	1.47	2.21	
12		1.56	3.33	1.56	.85	.88	2.56	1.45	2.18	
13		1.56	2.98	1.63	.84	.92	5.80	1.42	2.14	
14		1.57	2.80	2.31	.76	1.18	5.70	1.39	2.07	
15		1.60	2.70	1.60	.76	5.41	1.36	2.02	1.64	
16		1.64	2.61	1.53	1.48	1.91	4.43	1.33	1.98	
17		1.72	2.55	1.72	1.24	1.72	4.00	1.30	1.90	
18		1.98	2.51	1.77	1.15	2.10	3.67	1.28	1.90	
19		2.05	2.35	1.58	1.30	2.95	3.48	1.29	1.91	
20		2.17	2.27	1.54	1.58	2.66	3.31	1.31	1.86	
21		2.46	2.19	1.50	1.56	2.37	3.26	1.32	1.79	
22		2.55	2.13	1.42	2.04	2.13	3.32	1.72	1.65	
23		2.56	1.85	1.34	2.47	2.26	3.30	1.91	1.59	
24		2.66	1.84	1.29	3.01	2.04	3.04	1.98	1.54	
25		2.67	1.77	1.25	2.72	1.96	2.89	2.06		
26		2.75	1.75	2.27	2.56	2.17	3.11	2.18		
27		2.75	1.88	1.36	2.35	2.12	2.66	2.26		
28		2.93	1.83	1.27	2.24	2.08	2.34	2.40		
29		3.33	1.73	1.18	1.75	2.02	2.09	5.43		
30		3.76	1.83	.98	1.56	1.95	2.01	4.48		
31			1.72		1.46	2.32		4.12		
1901.										
1		2.20	2.66	1.66	6.01	1.07	.39	1.50	1.51	
2		2.22	2.63	1.64	5.74	1.03	.41	1.54	1.44	
3		2.25	2.50	1.60	5.23	1.00	.44	1.53	1.58	
4		2.30	2.46	1.62	4.98	.99	.45	1.62	1.68	
5		2.40	2.57	1.88	4.76	.96	.38	1.63	1.72	

Mean daily gage height, in feet, of Elkhorn River at Arlington, 1899–1903—Continued.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1901.										
6	.....	2.45	2.82	1.60	4.23	0.94	0.48	1.53	1.78	.....
7	.....	2.46	3.85	1.51	4.03	.90	.40	1.41	1.86	.....
8	.....	2.49	3.95	1.60	3.78	.91	.65	1.39	1.82	.....
9	.....	2.45	4.07	1.66	3.57	.92	.76	1.37	1.90	.....
10	.....	2.44	3.81	2.10	3.37	.87	.91	1.39	1.92	.....
11	.....	2.42	3.88	2.28	3.16	.87	.92	1.48	1.94	.....
12	.....	2.38	4.00	2.22	3.02	.81	1.10	1.55	1.88	.....
13	.....	2.45	3.66	2.23	2.83	.74	1.36	1.58	1.87	.....
14	.....	2.45	3.22	2.15	2.67	.77	1.42	1.60	1.86	.....
15	.....	2.54	2.92	2.24	2.50	.74	1.49	1.61	1.79	.....
16	.....	2.68	2.75	2.37	2.35	.71	1.56	1.69	1.78	.....
17	.....	2.76	2.55	2.34	2.22	.68	1.64	1.74	1.74	.....
18	.....	2.78	2.45	3.26	2.10	.70	1.63	1.70	1.66	.....
19	.....	2.92	2.34	3.80	1.99	.68	1.75	1.63	1.64	.....
20	.....	3.01	2.25	5.28	1.78	.62	1.60	1.59	1.66	.....
21	.....	3.08	2.15	6.06	1.75	.64	1.50	1.56	1.65	.....
22	.....	3.07	2.08	6.67	1.70	.62	1.37	1.52	1.61	.....
23	.....	3.11	2.05	7.17	1.61	.78	1.31	1.53	1.64	.....
24	.....	3.06	1.98	6.74	1.55	.61	1.39	1.51	1.65	.....
25	.....	2.95	1.96	6.38	1.45	.58	1.40	1.45	1.62	.....
26	.....	2.87	1.92	6.05	1.40	.60	1.35	1.49	1.64	.....
27	.....	2.88	1.89	5.93	1.35	.54	1.34	1.51	1.60	.....
28	.....	2.77	1.85	5.98	1.38	.55	1.35	1.52	1.61	.....
29	.....	2.72	1.84	6.10	1.28	.51	1.40	1.45	1.58	.....
30	.....	2.68	1.75	6.09	1.15	.46	1.42	1.48	1.54	.....
31	.....	.....	1.70	.....	1.12	.42	.....	1.50	.....	.....
1902.										
1	.....	2.24	3.20	1.90	1.80	4.95	3.47	4.20	2.88	2.01
2	.....	2.39	3.23	1.88	1.99	4.15	3.12	5.15	2.86	2.10
3	.....	2.51	3.30	1.82	2.20	3.37	2.80	5.07	2.76	.....
4	.....	2.73	3.12	1.72	2.85	3.00	2.64	4.80	2.75	.....
5	.....	2.89	2.71	1.82	3.57	2.75	2.52	4.73	2.72	.....
6	.....	2.83	2.44	1.88	5.80	2.56	2.40	4.60	2.67	.....
7	.....	2.75	2.31	1.75	6.17	2.35	2.24	4.39	2.63	.....
8	.....	2.67	2.23	1.74	5.90	2.21	2.20	4.26	2.58	.....
9	.....	2.62	2.15	1.99	8.16	2.14	2.17	4.17	2.60	.....
10	3.74	2.50	2.14	2.85	9.10	2.00	2.00	4.06	2.58	.....
11	3.34	2.39	2.08	2.76	8.78	1.95	1.97	4.01	2.56	.....
12	3.17	2.32	2.00	2.60	7.65	1.82	1.94	4.54	2.62	.....
13	3.19	2.21	2.01	2.31	7.66	1.88	1.90	5.14	2.87	.....
14	3.36	2.12	2.02	2.14	7.41	1.81	1.80	5.10	3.30	.....
15	3.37	2.13	1.98	2.10	6.10	2.25	1.76	4.71	3.16	.....
16	3.02	2.12	1.88	1.93	5.85	4.97	1.72	4.28	2.88	.....
17	3.33	2.07	1.87	1.82	5.52	5.50	1.68	4.02	2.76	.....
18	.....	1.98	1.82	1.91	6.11	4.29	1.61	3.86	2.64	.....
19	.....	1.96	1.77	2.27	7.11	3.59	1.55	3.72	2.58	.....
20	2.25	1.91	1.75	2.44	7.15	3.03	1.54	3.65	2.55	.....
21	2.32	1.84	1.80	2.15	6.92	2.70	2.06	3.49	2.47	.....
22	2.71	1.80	1.85	1.92	6.50	3.80	2.60	3.42	2.50	.....
23	2.57	1.77	1.93	1.81	5.69	3.44	3.25	3.39	2.47	.....
24	2.42	1.79	1.98	1.75	4.71	3.90	3.59	3.29	2.46	.....
25	2.35	1.75	2.00	1.72	4.06	4.18	3.58	3.22	2.36	.....
26	2.36	1.82	1.95	1.61	4.30	4.57	3.40	3.16	2.32	.....
27	2.28	1.92	1.89	1.60	4.22	5.18	3.45	3.06	2.28	.....
28	2.22	1.95	1.92	1.58	3.86	5.23	3.57	2.96	2.26	.....
29	2.23	2.11	1.90	1.70	3.51	5.06	3.46	2.95	2.24	.....
30	2.21	2.65	1.94	1.74	3.12	5.57	3.92	2.91	2.14	.....
31	2.18	.....	1.90	.....	3.66	3.90	.....	2.82	.....	.....
1903.										
1	.....	6.11	3.44	10.25	4.74	3.35	9.93	3.22	3.15	.....
2	.....	5.87	4.00	10.40	4.43	4.15	9.30	3.43	3.28	.....
3	.....	5.70	4.37	10.33	4.23	5.54	8.18	4.87	3.50	.....
4	.....	5.48	4.80	10.05	5.39	7.87	7.50	4.50	3.86	.....
5	.....	5.26	4.96	9.76	7.29	8.40	6.98	3.75	4.10	.....
6	.....	5.08	4.85	9.47	7.82	8.10	6.52	3.42	3.96	.....
7	.....	4.87	.....	9.37	7.91	7.37	5.96	3.27	3.78	.....
8	.....	4.71	4.45	9.25	7.07	6.34	5.42	3.75	3.60	.....
9	.....	4.50	4.25	9.17	6.25	5.74	5.10	4.88	3.55	.....
10	.....	4.40	4.12	9.05	5.85	5.28	4.94	4.86	3.44	.....

Mean daily gage height, in feet, of Elkhorn River at Arlington, 1899–1903—Continued.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1903.										
11		4.38	4.50	8.64	5.60	4.90	4.85	4.50	3.43	
12		4.49	6.41	8.15	5.33	4.68	5.20	4.50	3.34	
13		4.50	7.61	7.84	5.12	4.94	6.00	4.62	3.23	
14		4.37	7.89	7.48	4.93	4.87	6.42	4.80	3.25	
15		4.10	7.36	7.03	4.64	5.05	7.62	4.90	3.22	
16		3.91	6.64	6.38	4.30	4.65	7.68	4.88	3.20	
17		3.76	6.26	5.84	5.46	4.68	7.12	4.88	3.00	
18		3.60	6.05	5.50	7.31	4.72	6.06	4.64	1.70	
19		3.45	7.56	5.33	6.98	4.80	5.52	4.35	1.87	
20		3.37	7.19	5.20	6.61	4.54	5.38	4.12	2.20	
21		3.31	7.67	5.19	6.55	4.47	5.15	3.90	2.54	
22		3.30	8.55	5.40	4.86	4.30	5.00	3.72		
23		3.18	9.45	5.17	4.35	4.00	4.62	3.57		
24		3.12	8.50	5.43	4.05	3.72	4.20	3.43		
25	7.53	3.05	8.00	5.97	3.80	3.72	3.85	3.35		
26	7.16	2.92	8.18	5.68	3.55		3.65	3.30		
27	7.02	2.80	8.85	5.40	3.38	9.65	3.43	3.26		
28	6.93	2.82	8.40	5.22	3.22	10.42	3.32	3.12		
29	6.85	2.88	8.25	5.06	3.25	10.65	3.22	3.12		
30	6.72	3.13	9.20	4.87	3.24	10.63	3.20	3.18		
31	6.53		10.05		3.16	10.23		3.20		

Mean daily discharge, in second-feet, of Elkhorn River at Arlington, 1899–1903.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1899.									
1			808	1,988	1,184	571	388	300	
2			882	1,828	1,184	542	392	300	
3			793	1,809	1,443	509	344	291	
4			820	1,692	1,313	575	329	284	
5			945	1,618	1,233	628	314	284	
6			1,411	1,626	1,177	586	318	295	
7			2,290	1,727	1,072	646	325	295	
8			1,838	1,273	1,017	811	325	310	
9			1,781	1,155	1,017	700	322	314	
10				1,080	976	650	336	322	
11				1,069	976	688	340	336	
12				1,088	934	594	344	344	
13				4,315	960	597	340	351	
14				3,560	897	579	351	359	
15				2,925	867	606	333	362	
16				2,340	852	635	318	366	
17				2,572	826	632	314	359	
18				2,830	793	602	314	355	
19				1,847	770	557	314	359	
20				1,436	762	546	288	273	
21				1,188	733	490	295	381	
22				1,222	700	494	310	396	
23				1,220	710	485	325	403	
24				1,181	632	531	340	426	
25				1,129	602	538	344	434	
26				1,013	583	459	318	430	
27				1,054	575	456	314	434	
28		796		1,006	564	471	300	437	
29		789	2,480	1,054	564	456	288	434	
30		804	2,365	1,173	538	445	288	437	
31			2,390		538	384		430	
1900.									
1		559	1,673	692	384	498	808	723	1,855
2		555	1,615	718	378	454	637	679	2,000
3		559	1,542	667	387	429	548	670	1,837
4		551	1,495	745	381	404	498	638	1,749
5		526	1,435	722	448	398	474	621	1,574
6		518	1,400	731	416	378	461	601	1,400
7		504	1,428	740	395	361	454	582	1,184
8		501	1,526	692	387	347	448	570	1,092
9		484	1,698	637	367	332	454	559	967
10		498	2,283	629	355	322	426	545	901

Mean daily discharge, in second-feet, of Elkhorn River at Arlington, 1899–1903—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1900.									
11		491	2,105	613	364	327	555	537	881
12		484	1,518	590	347	347	1,021	530	871
13		484	1,286	617	344	358	4,160	519	858
14		491	1,178	927	325	435	4,074	508	823
15		501	1,120	605	325	705	3,683	498	794
16		515	1,076	578	544	709	2,501	484	776
17		544	1,044	654	461	629	2,077	477	740
18		646	1,021	675	433	794	1,775	470	740
19		676	937	597	480	1,250	1,615	474	745
20		745	901	582	582	1,081	1,479	481	723
21		896	863	567	570	927	1,442	484	692
22		943	833	537	772	808	1,485	633	633
23		958	705	508	983	871	1,463	714	609
24		1,015	700	491	1,293	767	1,300	745	590
25		1,026	671	474	1,120	831	1,208	780	.....
26		1,075	662	480	1,032	828	1,342	843	.....
27		1,081	718	512	922	806	1,076	881	.....
28		1,190	696	480	866	780	906	953	.....
29		1,447	658	451	646	753	790	3,656	.....
30		1,811	700	390	570	723	755	2,522	.....
31		.....	654	.....	533	896	.....	2,115	.....
1901.									
1		833	1,069	596	3,825	533	307	613	563
2		841	1,053	589	3,538	519	311	629	537
3		856	983	574	3,018	508	318	621	590
4		881	963	581	2,775	504	320	654	625
5		932	1,019	687	2,554	494	300	658	642
6		958	1,160	574	2,097	487	322	613	666
7		963	1,927	541	1,951	474	300	567	696
8		878	2,019	574	1,781	477	363	554	679
9		958	2,133	596	1,640	480	395	544	706
10		953	1,891	785	1,518	464	438	552	713
11		943	1,953	870	1,400	464	441	586	726
12		922	2,067	841	1,331	445	501	607	696
13		958	1,756	847	1,238	419	593	621	692
14		958	1,406	808	1,161	428	617	626	688
15		1,005	1,220	853	1,064	419	645	630	658
16		1,081	1,119	916	999	410	671	662	654
17		1,126	1,009	905	942	398	705	679	638
18		1,199	958	1,377	891	404	696	662	606
19		1,220	901	1,706	848	398	745	629	594
20		1,274	856	3,013	767	381	675	609	601
21		1,317	807	3,181	763	387	629	597	597
22		1,311	775	4,370	744	382	578	582	580
23		1,335	762	4,745	713	429	556	582	594
24		1,305	732	3,989	696	375	582	574	597
25		1,237	721	3,630	662	365	586	551	586
26		1,188	704	3,460	646	370	563	563	594
27		1,194	691	3,373	633	350	559	570	574
28		1,130	674	3,500	646	352	559	570	578
29		1,103	670	3,789	596	327	578	545	566
30		1,081	633	3,800	564	327	562	555	566
31		.....	613	.....	544	317	.....	563	.....
1902.									
1		968	1,518	776	585	2,653	1,400	2,096	1,196
2		1,048	1,582	767	650	1,846	1,202	3,066	1,184
3		1,115	1,640	740	740	1,250	1,037	2,936	1,126
4		1,244	1,495	696	1,026	1,037	968	2,686	1,120
5		1,342	1,236	740	1,442	896	922	2,619	1,103
6		1,305	1,070	767	3,749	799	881	2,469	1,175
7		1,256	999	709	4,203	705	818	2,253	1,053
8		1,214	952	705	3,816	642	813	2,174	1,026
9		1,184	912	813	7,586	570	818	2,086	1,037
10	2,029	1,115	906	1,280	9,568	552	758	1,982	1,036
11	1,673	1,053	876	1,220	8,917	529	740	1,982	1,015
12	1,534	1,015	838	1,126	6,462	487	722	2,512	1,048
13	1,550	958	843	968	6,654	497	700	3,199	1,190
14	1,689	912	847	886	6,206	471	654	3,162	1,463
15	1,698	917	828	862	4,105	629	633	2,809	1,367

Mean daily discharge, in second-feet, of Elkhorn River at Arlington, 1899–1903—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.									
16	1,421	912	776	780	3,762	2,522	613	2,344	1,196
17	1,664	886	771	731	3,324	3,114	593	2,086	1,126
18	.....	843	749	762	2,832	1,837	563	1,937	1,059
19	771	833	727	896	4,119	1,286	537	1,811	1,026
20	968	808	718	1,005	5,470	968	530	1,749	1,010
21	1,005	818	740	843	5,356	804	735	1,615	968
22	1,236	799	762	727	4,705	1,421	994	1,558	983
23	1,143	740	753	671	3,565	1,214	1,367	1,534	968
24	1,059	740	771	633	2,417	1,542	1,615	1,456	963
25	1,021	731	828	613	1,793	1,802	1,599	1,407	912
26	1,026	762	804	563	2,011	2,194	1,449	1,367	891
27	983	808	776	548	1,937	2,878	1,479	1,305	871
28	952	823	790	465	1,631	2,971	1,566	1,244	862
29	963	896	780	566	1,402	2,809	1,471	1,238	852
30	952	1,190	799	570	1,126	2,417	1,846	1,214	804
31	937	.....	780	.....	1,456	1,715	.....	1,161	.....
1903.									
1	.....	3,510	1,410	8,270	1,910	1,290	7,565	1,380	1,350
2	.....	3,295	1,745	8,510	1,745	1,810	6,670	1,530	1,440
3	.....	3,170	1,980	8,510	1,620	2,835	5,370	2,480	1,560
4	.....	3,000	2,295	7,665	2,440	4,850	4,650	2,225	1,780
5	.....	2,795	2,405	7,340	4,020	5,425	4,190	1,715	1,945
6	.....	2,675	2,330	6,865	4,505	5,110	3,765	1,500	1,845
7	.....	2,480	.....	6,670	4,650	4,370	3,295	1,410	1,745
8	.....	2,365	2,015	6,475	3,890	3,510	2,835	1,715	1,620
9	.....	2,225	1,875	6,235	3,255	3,000	2,595	2,515	1,590
10	.....	2,120	1,780	6,050	2,915	2,635	2,480	2,480	1,530
11	.....	2,120	2,050	5,535	2,755	2,330	2,405	2,225	1,530
12	.....	2,120	3,510	4,950	2,555	2,190	2,675	2,225	1,470
13	.....	2,190	4,555	4,600	2,405	2,405	3,380	2,295	1,410
14	.....	2,085	4,850	4,235	2,295	2,330	3,720	2,440	1,410
15	.....	1,910	4,325	3,765	2,085	2,480	4,800	2,515	1,380
16	.....	1,745	3,720	3,170	1,845	2,190	4,900	2,515	1,380
17	.....	1,650	3,380	2,635	2,675	2,225	4,325	2,515	1,260
18	.....	1,560	3,255	2,295	4,235	2,225	3,425	2,330	613
19	.....	1,470	4,555	2,155	3,975	2,295	2,955	2,120	675
20	.....	1,410	4,235	2,015	3,635	2,120	2,875	1,945	833
21	.....	1,380	4,695	2,015	3,595	2,050	2,675	1,810	1,010
22	.....	1,380	5,645	2,155	2,225	1,945	2,555	1,680	.....
23	.....	1,320	6,735	1,980	1,910	1,745	2,260	1,590	.....
24	.....	1,260	5,590	2,190	1,715	1,590	1,980	1,530	.....
25	4,800	1,202	5,110	2,555	1,560	1,590	1,780	1,470	.....
26	4,415	1,132	5,320	2,405	1,410	.....	1,650	1,440	.....
27	4,280	1,064	6,115	2,225	1,320	7,060	1,530	1,410	.....
28	4,235	1,064	5,590	2,120	1,202	8,185	1,440	1,320	.....
29	4,145	1,132	5,480	2,050	1,238	8,670	1,380	1,320	.....
30	4,020	1,260	6,605	1,945	1,238	8,590	1,380	1,380	.....
31	3,890	.....	7,665	.....	1,178	7,950	.....	1,380	.....

Estimated monthly discharge of Elkhorn River at Arlington, 1899–1903.

[Drainage area, 5,980 square miles.]

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
March.								
1902[a]	2,030	771	1,251	44,700	.....	.....	.....	1.24
1903[b]	4,800	3,890	4,255	59,100	.....	.....	.....	1.12
April.								
1900	1,810	484	742	44,200	0.124	0.13	3	4.84
1901	1,330	833	1,065	63,400	.178	.20	11	1.84
1902	1,342	731	974	57,900	.163	.18	11	1.71
1903	3,510	1,064	1,936	115,200	.324	.36	14	2.42
May.								
1899	2,480	793	1,567	96,300	.262	.30	5	6.02
1900	2,280	654	1,166	71,700	.195	.22	6	3.78
1901	2,130	613	1,136	69,800	.190	.22	9	2.53
1902	1,640	718	931	57,200	.156	.18	7	2.64
1903	7,660	1,410	4,027	239,600	.673	.75	9	8.15
June.								
1899	4,320	1,010	1,701	101,200	.285	.31	5	6.04
1900	927	390	610	36,300	.105	.11	6	1.88
1901	4,745	541	1,869	111,200	.313	.35	5	7.66
1902	1,220	465	781	46,500	.131	.14	2	5.80
1903	8,510	1,940	4,319	257,000	.722	.81	27	2.95
July.								
1899	1,440	538	871	53,600	.145	.17	6	2.74
1900	1,290	325	562	34,600	.094	.10	2	4.80
1901	3,820	544	1,372	84,400	.229	.27	28	.96
1902	9,570	585	3,633	223,400	.608	.69	10	6.93
1903	4,650	1,178	2,516	154,700	.421	.48	8	6.10
August.								
1899	811	384	563	34,600	.094	.11	2	4.74
1900	1,250	322	627	38,600	.105	.12	3	4.24
1901	533	317	421	25,900	.070	.08	8	1.00
1902	3,114	471	1,453	89,300	.242	.33	8	4.15
1903	8,670	1,290	3,567	212,200	.596	.66	10	6.91
September.								
1899	392	288	326	19,400	.055	.06	6	.94
1900	4,160	426	1,331	79,200	.222	.25	7	3.67
1901	745	300	515	30,600	.086	.10	1	7.61
1902	1,850	530	1,001	59,600	.167	.19	4	4.28
1903	7,560	1,380	3,250	193,400	.543	.61	39	1.58
October.								
1899	436	284	361	22,200	.060	.07	9	.74
1900	3,660	470	824	50,700	.137	.16	4	3.70
1901	679	544	599	36,800	.100	.12	6	1.98
1902	3,200	1,160	2,034	125,000	.340	.39	31	1.24
1903	2,510	1,320	1,884	115,800	.315	.36	19	1.87
November.								
1900	1,880	590	1,034	61,500	.172	.19	105	.18
1901	726	537	627	37,300	.105	.11	11	.99
1902	1,460	804	1,051	62,500	.176	.19	43	.44
1903	1,940	613	1,399	82,200	.234	.26	22	1.18

[a] 21 days in March.

[b] March 25 to 31.

MISCELLANEOUS MEASUREMENTS IN THE PLATTE BASIN.

The following discharge measurements have been made of streams in the Platte drainage basin.

Miscellaneous discharge measurements in the drainage basin of Platte River, 1894–1904.

Stream.	Locality.	Date.	Hydrographer.	Discharge.
				Sec.-ft.
Beaver Creek	Genoa	Sept. 17, 1894	O. V. P. Stout	71
Do	do	July 14, 1896	do	110
Do	do	Aug. 14, 1896	W. J. McEathron	111
Do	do	June 21, 1898	O. V. P. Stout	150
Do	do	Aug. 8, 1900	do	50
Do	do	July 12, 1901	do	75
Do	do	July 30, 1901	do	86
Do	Albion	July 21, 1896	do	47.4
Do	do	Apr. 23, 1898	Glenn E. Smith	89
Do	do	Dec. 3, 1901	B. E. Forbes	92
Do	Sec. 24, T. 17 N., R. 4 W. *a*	Aug. 8, 1900	O. V. P. Stout	7.2
Birdwood Creek	Sec. 34, T. 15 N., R. 33 W	Sept. 24, 1892		126
Do	Sec. 35, T. 15 N., R. 33 W	May 25, 1899	H. H. Pickens	183
Do	do	Aug. 29, 1901	H. O. Smith	183
Do	Sec. 15, T. 15 N., R. 33 W. *b*	May 7, 1898	C. B. Channel	123
Do	do	Oct. 30, 1901	B. E. Forbes	170
Do	do	Apr. 23, 1903	H. O. Smith	162
Do	Sutherland	Sept. 9, 1896	O. V. P. Stout	*c* 133
Blue Creek	Lown Bridge	Nov. 5, 1892		105
Do	NE. ¼ sec. 30, T. 16 N., R. 42 W.	Mar. 28, 1897	Adna Dobson	115
Do	Sec. 33, T. 17 N., R. 42 W	Aug. 31, 1898	A. B. McCoskey	81
Do	S. line sec. 18, T. 17 N., R. 42 W.	May 22, 1899	H. H. Pickens	90
Do	Sec. 19, T. 16 N., R. 42 W. *d*	July 26, 1900	E. D. Johnson	27.4
Do	do. *e*	do	do	14.1
Do	do	Aug. 18, 1902	H. O. Smith	50
Do	Sec. 6, T. 16 N., R. 42 W	July 17, 1902	do	90
Do	Sec. 18, T. 16 N., R. 42 W	Aug. 31, 1904	do	48
Bratt's ditch	Sutherland	Sept. 9, 1896	O. V. P. Stout	28.2
Buffalo Creek	Sec. 33, T. 9 N., R. 18 W	July 5, 1902	H. O. Smith	6.4
Do	Sec. 30, T. 10 N., R. 20 W	do	do	2
Calamus River	Burwell	July 10, 1896	O. V. P. Stout	368
Do	do	Mar. 25, 1902	B. E. Forbes	411
Do	do	May 17, 1898	Glenn E. Smith	372
Do	Sec. 8, T. 24 N., R. 19 W	Sept. 20, 1899	C. B. Channel	152
Cedar River	Fullerton	Sept. 15, 1894	O. V. P. Stout	210
Do	do	July 11, 1896	do	238
Do	do	July 21, 1898	do	277
Do	do	Nov. 21, 1901	Adna Dobson	291
Do	do	do	B. E. Forbes	309
Do	Cedar Rapids	July 21, 1896	O. V. P. Stout	212
Do	Ericson	Mar. 16, 1895	W. J. McEathron	152
Do	do	June 1, 1895	do	214
Do	do	Aug. —, 1895	do	112
Do	do. *f*	May 17, 1899	Glenn E. Smith	107
Do	do. *g*	do	do	113
Cedar River, Dry Brook. *h*	do	May 17, 1899	Adna Dobson	5
Cedar Creek	Sec. 18, T. 14 N., R. 35 W	June 17, 1903	H. O. Smith	1.7
Clear Creek	Sec. 19, T. 16 N., R. 41 W	Nov. 23, 1896	Adna Dobson	12.8
Do	Sec. 32, T. 16 N., R. 41 W. *i*	May 19, 1899	H. H. Pickens	7.8
Do	Sec. 5, T. 14 N., R. 34 W	Dec. 16, 1899	C. B. Channel	3.4
Do	Sec. 29, T. 16 N., R. 41 W	Aug. 8, 1901	H. O. Smith	10.7
Coldwater Creek	Sec. 26, T. 18 N., R. 46 W	May 25, 1898	C. B. Channel	2.9
Coon Creek	Sec. 34, T. 15 N., R. 37 W	May 19, 1898	do	.8
Dismal River	Dunning	Aug. 22, 1894	G. H. Lawrence	435
Do	do	Aug. 23, 1895	O. V. P. Stout	29.4
Do	do	Apr. 28, 1898	Glenn E. Smith	369
Do	do	Nov. 1, 1898	do	351
Do	do	Apr. 21, 1899	A. B. McCoskey	334
Do	do	Sept. 15, 1904	R. D. Hubbard	395
Elkhorn River	Arlington	Aug. —, 1894	A. Rosewater	214
Do	do	May 26, 1898	Glenn E. Smith	1,808
Do	do	Dec. 15, 1898	do	422
Do	do	May 26, 1904	J. C. Stevens	1,343
Do	do	do	do	1,284
Do	Atkinson	Oct. 2, 1896	Adna Dobson	11.1
Do	do	May 24, 1898	A. B. McCoskey	110

a Below diversion of Great Eastern canal.
b Above Beauchamp's ditch.
c Bratt's ditch diverting 28.2 second-feet.
d Above Graff's dam.
e Below head of Graff's ditch.
f Above dam.
g Below dam.
h At mouth.
i 700 yards below Barber & Marsh head-gate

Miscellaneous discharge measurements in the drainage basin of Platte River—Cont'd.

Stream.	Locality.	Date.	Hydrographer.	Discharge.
				Sec.-ft.
Elkhorn River	Waterloo	Aug. 15,1896	O. V. P. Stout	280
Do	do	July 23,1896	do	5
Do	do	July 17,1896	do	495
Do	O'Neill	June 23,1897	do	20.6
Do	do	June 11,1898	Glenn E. Smith	288
Do	do	Aug. 17,1898	C. B. Channel	31.3
Do	Ewing	Sept. 3,1897	O. V. P. Stout	9.8
Do	do	Aug. 18,1898	C. B. Channel	54
Elkhorn River, North Fork.	Norfolk	July 16,1896	O. V. P. Stout	70
Do	do	Mar. 24,1897	Adna Dobson	701
Do	do	May 5,1897	do	166
Do	do	May 24,1897	do	77
Do	do	July 30,1897	O. V. P. Stout	70
Do	do	June 20,1898	do	162
Do	do	Apr. 27,1899	Glenn E. Smith	122
Do	do	May 25,1899	do	414
Do	do	Feb. 20,1899	do	119
Do	do	Aug. 17,1899	do	81
Do	do	Sept. 25,1899	do	85
Do	Norfolk Junction Bridge	May 27,1900	O. V. P. Stout	76
Do	do	Aug. 3,1900	do	89
Do	do	May 13,1901	C. B. Channel	550
Do	do	July 31,1901	do	149
Do	do	Mar. 21,1902	J. C. Stevens	118
Do	do	Apr. 13,1902	do	150
Do	do	May 12,1902	do	116
Do	do	June 16,1902	do	137
Do	do	July 26,1902	do	168
Do	do	Aug. 22,1902	do	170
Do	do	Sept. 29,1902	do	242
Do	do	Nov. 14,1902	do	118
Do	do	Aug. 26,1903	do	185
Do	do	June 24,1903	do	386
Do	do	May 25,1903	do	498
Elkhorn River, South Fork.	Ewing	Sept. 3,1897	O. V. P. Stout	18.2
Enterprise canal	Sec. 24, T. 23 N., R. 57 W.	July 29,1903	J. C. Stevens	41.9
Fremont Creek	W. line sec. 18, T. 13 N., R. 30 W.	Aug. 13,1903	H. O. Smith	2.9
Glenwood Creek	Sec. 15, T. 18 N., R. 50 W.	June 10,1904	R. H. Willis	6
Golden Creek	Sec. 25, T. 15 N., R. 39 W.	Aug. 19,1902	H. O. Smith	.6
Goose Creek	Sec. 10, T. 22 N., R. 27 W.	Apr. 27,1899	C. B. Channel	30.3
Do	Sec. 18, T. 25 N., R. 24 W.	Sept. 13,1904	R. D. Hubbard	14.4
Horse Creek	At Mitchell flume	Oct. 16,1892		86
Do	Nebr.-Wyo. state line	Oct. 15,1897	A. B. McCoskey	10.5
Do	do	June 16,1899	do	11.1
Lake Creek	NW. ¼ sec. 14, T. 14 N., R. 36 W.	June 17,1903	H. O. Smith	2.4
Lawrence Fork	Sec. 36, T. 19 N., R. 52 W.	June 10,1901	R. H. Willis	1.7
Do	do	July 22,1902	F. Dobson	1.4
Do	Sec. 11, T. 18 N., R. 52 W.	do	R. H. Willis	1.6
Do	do	Aug. 20,1903	H. O. Smith	2.8
Do	Sec. 1, T. 18 N., R. 52 W.	July 29,1902	R. H. Willis	2.9
Do	do	Aug. 20,1903	H. O. Smith	4
Do	Sec. 15, T. 18 N., R. 52 W.	July 31,1902	R. H. Willis	2.2
Lodgepole Creek	Kimball	May 26,1896	Adna Dobson	4.5
Do	do	Sept. 12,1900	E. D. Johnson	4.9
Do	do	Sept. 15,1900	do	1.1
Do	do	Sept. 18,1900	do	4.3
Do	do	June 2,1902	H. O. Smith	5.6
Do	do	June 15,1904	do	2.1
Do	do	Sept. 6,1904	do	13.4
Do	Sec. 34, T. 14 N., R. 49 W.	May 15,1899	H. H. Pickens	11
Do	Bet. secs. 33 and 34, T. 15 N., R. 56 W.	Aug. 9,1899	E. D. Johnson	7.4
Do	W. line T. 15 N., R. 55 W.	do	do	2.4
Do	do	Sept. 10,1900	do	1.3
Do	Sec. 29, T. 15 N., R. 55 W.	Aug. 11,1899	do	2
Do	do. [a]	May 25,1903	H. O. Smith	4.4
Do	do	May 4,1904	do	20.5
Do	W. line sec. 29, T. 15 N., R. 55 W.	July 24,1903	do	6.6
Do	do	Oct. 30,1903	do	15.5
Do	do	Nov. 7,1903	do	21.6
Do	do	Nov. 16,1903	do	20.4
Do	Sec. 33, T. 15 N., R. 56 W. [b]	Aug. 10,1899	E. D. Johnson	6.5
Do	do	Apr. 28,1904	H. O. Smith	14.4
Do	do	May 5,1904	do	48.2

[a] Head of Bay State ditch.

[b] One-half mile above Kinney ditch.

Miscellaneous discharge measurements in the drainage basin of Platte River—Cont'd.

Stream.	Locality.	Date.	Hydrographer.	Discharge.
				Sec.-ft.
Lodgepole Creek	Sec. 33, T. 15 N., R. 57 W.[a]	Aug. 10, 1899	E. D. Johnson	15.6
Do	do	Aug. 10, 1900	do	12.3
Do	do	June 2, 1903	H. O. Smith	12.8
Do	Sec. 33, T. 14 N., R. 49 W	May 15, 1900	E. D. Johnson	3.9
Do	do	Aug. 14, 1900	do	6.4
Do	Sec. 35, T. 14 N., R. 49 W.[b]	May 15, 1900	do	6.3
Do	Sec. 14, T. 14 N., R. 51 W	May 17, 1900	do	2.3
Do	do	Aug. 17, 1900	do	2.4
Do	do	July 25, 1903	H. O. Smith	0
Do	Sec. 31, T. 14 N., R. 47 W	May 18, 1900	E. D. Johnson	2.6
Do	do	Aug. 16, 1900	do	2.5
Do	Sec. 3, T. 13 N., R. 46 W	May 21, 1900	do	2.3
Do	Sec. 12, T. 12 N., R. 45 W	May 22, 1900	do	1.3
Do	Sec. 23, T. 13 N., R. 45 W	May 23, 1900	do	7.3
Do	Sec. 36, T. 15 N., R. 57 W	May 25, 1900	do	4.8
Do	Sec. 2, T. 14 N., R. 58 W	May 26, 1900	do	9.2
Do	do	June 3, 1903	H. O. Smith	10.1
Do	Sec. 36, T. 13 N., R. 45 W	Aug. 7, 1900	E. D. Johnson	3.1
Do	Sec. 3, T. 14 N., R. 58 W	Aug. 8, 1900	do	6.2
Do	Sec. 23, T. 15 N., R. 55 W	Aug. 9, 1900	do	6.3
Do	Sec. 3, T. 12 N., R. 45 W	Aug. 10, 1900	do	1.3
Do	Sec. 2, T. 13 N., R. 46 W	Aug. 22, 1900	do	2.8
Do	Sec. 30, T. 15 N., R. 55 W.[c]	Sept. 10, 1900	do	2.4
Do	do.[d]	do	do	1.1
Do	Sec. 26, T. 13 N., R. 45 W.[e]	Oct. 3, 1900	do	3.3
Do	Sec. 9, T. 14 N., R. 51 W	July 1, 1901	H. O. Smith	5.6
Do	do	July 25, 1903	do	3.8
Do	do	Apr. 27, 1904	do	6.6
Do	Sec. 29, T. 14 N., R. 48 W	July 2, 1901	do	4
Do	Sec. 29, T. 14 N., R. 47 W	do	do	2.2
Do	Sec. 31, T. 14 N., R. 46 W	July 3, 1901	do	3.4
Do	do	Sept. 8, 1904	do	3.3
Do	Sec. 12, T. 14 N., R. 59 W	July 30, 1901	do	2.9
Do	Sec. 27, T. 15 N., R. 56 W	July 31, 1901	do	6.2
Do	Sec. 36, T. 14 N., R. 47 W	Apr. 13, 1902	do	4
Do	Sec. 35, T. 15 N., R. 55 W	Apr. 25, 1902	do	12
Do	Sec. 25, T. 15 N., R. 56 W	July 2, 1902	do	7.5
Do	do	May 29, 1903	do	31
Do	W. line sec. 25, T. 15 N., R. 56 W.	July 23, 1903	do	7.4
Do	Sec. 31, T. 15 N., R. 56 W	July 2, 1902	do	10.5
Do	do	June 1, 1903	do	12.5
Do	do.[f]	July 23, 1903	do	.5
Do	do	Apr. 30, 1904	do	12.4
Do	Sec. 26, T. 15 N., R. 55 W	Apr. 24, 1903	do	12.6
Do	do	July 24, 1903	do	4.6
Do	Sec. 26, T. 15 N., R. 56 W	Apr. 25, 1903	do	16.6
Do	Sec. 10, T. 14 N., R. 51 W	June 18, 1903	do	5.4
Do	do	July 25, 1903	do	3.8
Do	do	Apr. 27, 1904	do	7.2
Do	Sec. 34, T. 15 N., R. 56 W	July 23, 1903	do	7.5
Do	W. line sec. 30, T. 15 N., R. 54 W.	July 24, 1903	do	0
Do	W. line sec. 3, T. 14 N., R. 52 W.	July 25, 1903	do	3.2
Do	Center sec. 8, T. 14 N., R. 51 W.	do	do	3.5
Do	Sec. 15, T. 14 N., R. 51 W	do	do	2.9
Do	Sec. 8, T. 14 N., R. 51 W	Apr. 27, 1904	do	8.6
Do	Sec. 8, T. 14 N., R. 58 W	May 3, 1904	do	34.7
Do	Sec. 24, T. 15 N., R. 56 W	Sept. 8, 1904	do	8.7
Do	Lodge Pole station	Oct. 8, 1900	E. D. Johnson	2.1
Do	Chappell	Oct. 18, 1900	do	3.1
Do	Sidney	July 1, 1901	H. O. Smith	6.7
Do	Sec. 35, T. 15 N., R. 56 W	May 27, 1903	do	31.3
Do	Sec. 31, T. 15 N., R. 57 W	June 1, 1903	do	15.8
Do	Nebr.-Wyo. state line	May 2, 1904	do	4.3
Do	1 mile east of state line	do	do	4.6
Lonergan Creek	Sec. 17, T. 15 N., R. 39 W	May 22, 1898	C. B. Channel	6.1
Do	Sec. 19, T. 15 N., R. 39 W	Aug. 18, 1902	H. O. Smith	2.5
Lookingglass Creek	Sec. 4, T. 17 N., R. 2 W.[g]	July —, 1896	W. J. McEathron	15
Loup River	Fullerton	Sept. 16, 1894	O. V. P. Stout	1,704
Do	do	July 11, 1896	do	2,900
Do	Sec. 13, T. 17 N., R. 2 W	Aug. 19, 1894	do	1,335
Mathews Creek	Sec. 28, T. 15 N., R. 37 W	May 19, 1898	C. B. Channel	1.7
Middle Loup River	Gates	Aug. 25, 1894	G. W. Lawrence	850
Do	Sec. 33, T. 25 N., R. 33 W	Aug. 20, 1895	O. V. P. Stout	41.8

[a] Above Young ditch.
[b] One-half mile west of Jones dam.
[c] Above Polly ditch.
[d] At bridge below Polly ditch.
[e] Above Neuman dam.
[f] Below Kinney dam.
[g] Near mouth.

Miscellaneous discharge measurements in the drainage basin of Platte River—Cont'd.

Stream.	Locality.	Date.	Hydrographer.	Discharge.
				Sec-ft.
Middle Loup River	Sec. 32, T. 19 N., R. 21 W	Oct. 11, 1904	Adna Dobson	878
Do	Mullen	Aug. 20, 1895	O. V. P. Stout	120
Do	Seneca	Aug. 21, 1895	do	216
Do	do	Aug. 30, 1896	do	212
Do	do	Apr. 28, 1898	Glenn E. Smith	222
Do	do	Nov. 1, 1898	do	198
Do	do	May 2, 1899	C. B. Channel	225
Do	do	May 24, 1904	R. D. Hubbard	205
Do	Thedford	Apr. 22, 1895	O. V. P. Stout	284
Do	do	May 24, 1904	R. D. Hubbard	271
Do	do	June 22, 1904	J. A. Green	232
Do	Dunning	Apr. 23, 1895	O. V. P. Stout	322
Do	do	do	do	615
Do	do	Aug. 30, 1896	do	323
Do	do	Apr. 28, 1898	Glenn E. Smith	410
Do	do	Nov. 1, 1898	do	433
Do	do	Apr. 21, 1899	A. B. McCoskey	408
Do	Loup City	Aug. 29, 1895	O. V. P. Stout	879
Do	Boelus	May 28, 1897	Adna Dobson	837
Do	Arcadia	Apr. 18, 1899	A. B. McCoskey	810
Do	do	June 10, 1904	R. D. Hubbard	2,162
Do	St. Paul	May 23, 1902	B. E. Forbes	1,538
Do	do	June 10, 1904	R. D. Hubbard	[a] 12,800
Mitchell canal	At flume over Horse Creek	Oct. 16, 1892		24
Mud Creek	Litchfield	July 25, 1904	J. A. Green	37
North Loup River	Moulton	Nov. 2, 1894	G. W. Lawrence	460
Do	Burwell	July 9, 1896	O. V. P. Stout	625
Do	do	May 16, 1899	Glenn E. Smith	984
Do	do	Mar. 25, 1902	B. E. Forbes	1,088
Do	Below mouth Wanaduza Creek.	July 24, 1897	O. V. P. Stout	130
Do	Brownlee	May 1, 1899	C. B. Channel	360
Do	do	Sept. 23, 1899	do	196
Do	do	June 20, 1904	R. D. Hubbard	147
Do	do	do	do	160
Do	Brewster	Sept. 21, 1899	C. B. Channel	362
Do	do	Sept. 14, 1904	R. D. Hubbard	467
Do	St. Paul	May 23, 1902	B. E. Forbes	1,186
Do	do	June 10, 1904	R. D. Hubbard	2,219
Do	Cascade	June 21, 1904	J. A. Green	227
North Platte River	Douglas, Wyo	June 3, 1891	Wyoming state engineer.	10,130
Do	do	Dec. 4, 1891	do	807
Do	do	Nov. 5, 1892	do	595
Do	Fairbanks, Wyo	Oct. 13, 1891	do	579
Do	Lewellen	Sept. 1, 1898	A. B. McCoskey	5
Do	do	Aug. 7, 1901	H. O. Smith	100
Do	do	Aug. 8, 1901	do	758
Do	do	Aug. 30, 1904	do	60
Do	do	May 22, 1899	H. H. Pickens	15,902
Do	Gering	Nov. 7, 1898	A. B. McCoskey	593
Do	do	June 14, 1895		11,350
Do	do	June 17, 1895		10,963
Do	do	June 14, 1899	A. B. McCoskey	16,105
Do	do	Sept. 26, 1900	do	333
Do	do	Nov. 5, 1900	do	625
Do	do	June 1, 1901	O. V. P. Stout	10,360
Do	Camp Clarke	June 27, 1901	R. H. Willis	5,800
Do	do	July 10, 1901	do	2,900
Do	Sec. 18, T. 14 N., R. 33 W	July 28, 1901	H. O. Smith	394
Do	do	Aug. 7, 1901	E. F. Seeberger	150
Do	Sec. 3, T. 23 N., R. 58 W	Aug. 26, 1902	F. Dobson	31
Do	do	Aug. 28, 1902	R. H. Willis	31
Do	do	Sept. 8, 1902	do	8
Do	do	Sept. 22, 1902	do	630
Do	Sec. 18, T. 14 N., R. 36 W	Aug. 28, 1904	H. O. Smith	30
Do	Sutherland	Aug. 27, 1904	do	27
Oak Creek	Sec. 17, T. 10 N., R. 6 E	May 10, 1899	McCoy and Pickens	27.5
Do	do	July 3, 1899	do	[b] 703
Do	Dannebrog	May 19, 1899	Glenn E. Smith	5
Pawnee Creek	Sec. 19, T. 13 N., R. 27 W.[c]	Apr. 25, 1898	C. B. Channel	4.9
Do	Sec. 12, T. 13 N., R. 28 W.[d]	do	do	4.7
Paxton Spring	Sec. 19, T. 15 N., R. 27 W	May 7, 1902	H. O. Smith	.8
Plain Creek	Sec. 27, T. 31 N., R. 34 W	Oct. 26, 1900	A. B. McCoskey	29
Platte River	Columbus	Sept. 17, 1894	O. V. P. Stout	0
Do	do	Oct. 6, 1894	do	0
Do	Fremont	Aug. 14, 1894	do	1,420
Do	do	Aug. —, 1894	A. Rosewater	1,209
Do	do	Aug. 13, 1900	O. V. P. Stout	2,300

[a] Flood; gage height, 3.60. [b] Flood. [c] Above Plummer's ditch. [d] Above Holcomb's ditch.

Miscellaneous discharge measurements in the drainage basin of Platte River—Cont'd.

Stream.	Locality.	Date.	Hydrographer.	Discharge.
				Sec.-ft.
Platte River	Fremont	Aug. 11, 1901	O. V. P. Stout	1,152
Do	Kearney	June 29, 1896	do	0
Do	do	July 22, 1901	H. O. Smith	0
Do	do	Sept. 7, 1902	J. C. Stevens	0
Do	Grand Island	Sept. 7, 1898	O. V. P. Stout	0
Do	do	Sept. 15, 1898	do	12
Do	do	Nov. 2, 1898	Glenn E. Smith	0
Do	do	Oct. 1, 1903	J. C. Stevens	0
Do	do	Aug. 28, 1904	R. D. Hubbard	0
Do	Central City	Sept. 8, 1899	Glenn E. Smith	50
Do	Lexington	May 14, 1901	H. O. Smith	5,804
Do	do	May 24, 1901	do	10,167
Do	do	June 5, 1901	do	9,888
Do	do	June 18, 1901	do	12,406
Do	do	July 8, 1901	do	2,501
Do	do	July 20, 1901	do	0
Do	Ashland	Sept. 14, 1903	J. C. Stevens	10,974
Do	do	Aug. 31, 1903	do	38,631
Do	South Bend	May 5, 1903	do	13,179
Do	Valley	May 7, 1904	do	3,976
Do	Sec. 29, T. 12 N., R. 26 W.	Sept. 13, 1904	H. O. Smith	36
Prairie Creek	Sec. 26, T. 16 N., R. 5 W.	Nov. 21, 1901	B. E. Forbes	7
Pumpkinseed Creek	Sec. 12, T. 19 N., R. 50 W.	Oct. 8, 1892		32
Do	Sec. 25, T. 19 N., R. 51 W.	June 17, 1903	R. D. Hubbard	.6
Do	Sec. 13, T. 19 N., R. 50 W.	June 28, 1896	O. V. P. Stout	22.2
Do	Bet. secs. 25, 30, T. 19 N., R. 50 W.	June 17, 1903	R. D. Hubbard	4.4
Do	Sec. 25, T. 19 N., R. 51 W.	do	do	2.7
Do	Sec. 30, T. 19 N., R. 50 W.	do	do	3.4
Do	do	May 29, 1903	R. H. Willis	7.9
Do	Lot 1, sec. 7, T. 19 N., R. 55 W.	July 16, 1903	do	1.3
Do	Sec. 33, T. 19 N., R. 52 W.	June 16, 1904	H. O. Smith	11.4
Salt Creek	Lincoln	Feb. 5, 1897		38
Do	do	Aug. 17, 1900	Adna Dobson	[a] 5,807
Do	do	May 20, 1901	O. V. P. Stout	44
Do	do	July 7, 1902	Adna Dobson	[a] 5,438
Do	do	July 10, 1902	do	[a] 10,136
Do	do	Oct. 1, 1902	B. E. Forbes	92
Do	Ashland	Sept. 14, 1903	J. C. Stevens	932
Do	do	Aug. 31, 1903	do	216
Sand Creek	Sec. 14, T. 15 N., R. 40 W.	Aug. 19, 1902	H. O. Smith	1.3
Shell Creek	Platte Center	July 21, 1896	O. V. P. Stout	47
Do	do	July 23, 1896	do	15.3
Do	Schuyler	July 24, 1896	do	26.3
Skunk Creek	Sec. 1, T. 14 N., R. 37 W.	May 18, 1898	C. B. Channel	2
South Loup River	Callaway	Aug. 28, 1896	O. V. P. Stout	48
Do	do	Aug. 3, 1898	C. B. Channel	83
Do	do	July 26, 1904	J. A. Green	82
Do	Ravenna	Aug. 31, 1895	O. V. P. Stout	296
Do	do	Aug. 29, 1896	do	142
Do	Georgetown	Sept. 10, 1896	G. H. Lawrence	68
Do	Ravenna	Mar. 11, 1903	J. C. Stevens	1,723
Do	do	May 13, 1903	do	399
Do	Arnold	Aug. 4, 1898	C. B. Channel	31.5
Do	St. Michaels	May 28, 1897	Adna Dobson	220
Do	Sec. 27, T. 18 N., R. 26 W.	July 27, 1904	J. A. Green	9
Do	Sec. 31, T. 17 N., R. 24 W.	July 28, 1904	do	56
Do	Sec. 30, T. 15 N., R. 21 W.	do	do	103
South Platte River	North Platte	Nov. 2, 1892	U. S. Geol. Survey	460
Do	do	Nov. 22, 1892	do	645
Do	do	June 29, 1896	do	0
Do	do	May 14, 1897		1,949
Do	do	June 21, 1897		4,427
Do	do	Aug. 13, 1897		2,880
Do	do	June 19, 1899	Glenn E. Smith	0
Do	do	Apr. 19, 1899	do	883
Do	do	May 6, 1899	do	87
Do	do	May 22, 1899	do	88
Do	do	June 6, 1899	do	0
Do	do	Dec. 20, 1900	Adna Dobson	963
Do	do	July 17, 1901	O. V. P. Stout	0
Do	do	Apr. 9, 1902	H. O. Smith	0
Do	do	May 20, 1902	do	207
Do	do	Oct. 31, 1903	J. C. Stevens	0
Do	do	June 29, 1903	do	0
Do	do	May 8, 1903	do	50
Do	do	Apr. 2, 1903	do	909
Do	do	Mar. 26, 1904	do	0
Do	do	May 27, 1904	R. D. Hubbard	11

[a] Flood.

Miscellaneous discharge measurements in the drainage basin of Platte River—Cont'd.

Stream.	Locality.	Date.	Hydrographer.	Discharge.
				Sec.-ft.
South Platte River	North Platte	June 13, 1904	J. C. Stevens	2,231
Do	do	Mar. 31, 1905		382
Do	do	June 14, 1905		7,614
Do	do	July 13, 1905		170
Do	Ogallala	Apr. 17, 1904	Adna Dobson	0
Do	Sutherland	May 23, 1899	H. H. Pickens	50
Do	Julesburg, Colo	Oct. 27, 1892	U. S. Geol. Survey	653
Do	do	Sept. 22, 1903	E. C. Murphy	4
Do	do	May 9, 1903	J. C. Stevens	25
Do	do	Apr. 1, 1903	do	1,145
Do	do	May 27, 1904	do	130
Spottedtail Creek	Sec. 2, T. 23 N., R. 56 W	Apr. 30, 1904	R. D. Hubbard	1
Spring Creek	Sec. 28, T. 16 N., R. 41 W	May 23, 1898	C. B. Channel	4.6
Do	Sec. 29, T. 16 N., R. 41 W	do	do	6.7
Do	Sec. 29, T. 15 N., R. 37 W	May 19, 1898	do	1.1
Do	Sec. 25, T. 10 N., R. 21 W	July 11, 1901	H. O. Smith	4.4
Do	Sec. 30, T. 10 N., R. 21 W	Aug. 18, 1902	do	1
Do	Sec. 36, T. 14 N., R. 47 W	Apr. 23, 1902	do	2.4
Do	Sec. 30, T. 15 N., R. 37 W	May 7, 1902	do	2.5
Union Creek	Madison	July 23, 1896	O. V. P. Stout	38.3
Victoria Creek	Sec. 1, T. 19 N., R. 21 W	July 28, 1896	Adna Dobson	5.2
Do	do	Oct. 11, 1904	do	2.6
Western ditch	W. line sec. 18, T. 12 N., R. 42 W.	May 9, 1903	J. C. Stevens	22.5
Do	W. line sec. 9, T. 12 N., R. 42 W.	do	do	21.5
White Horse Creek	Sec. 5, T. 14 N., R. 30 W. [a]	May 3, 1898	C. B. Channel	2.3
Whitetail Creek	Sec. 22, T. 15 N., R. 38 W. [b]	May 20, 1898	do	24.7
Do	Sec. 15, T. 15 N., R. 33 W. [c]	do	do	24.6
Do	Sec. 36, T. 15 N., R. 38 W. [d]	do	do	26.1
Do	South line sec. 36, T. 15 N., R. 38 W.	May 7, 1902	H. O. Smith	24.7
Do	North line sec. 36, T. 15 N., R. 38 W.	do	do	36
Do	NE. ¼ sec. 26, T. 15 N., R. 38 W.	do	do	33
Wood River	Glenwood	Aug. 8, 1898	C. B. Channel	5.8
Do	Sec. 12, T. 9 N., R. 16 W	Sept. 7, 1902	J. C. Stevens	27.3

[a] Above Lampluph Lake.
[b] Above Whitetail canal.
[c] Above Reed ditch.
[d] Above Holloway canal.

PRECIPITATION IN THE PLATTE DRAINAGE BASIN.

The following is a list of the precipitation stations in the Platte basin:

Rainfall stations in drainage basin of Platte River.

Station.	County.	Latitude.	Longitude.	Elevation.	Length of record.
		° ′	° ′	*Feet.*	*Years.*
Lincoln	Lancaster	40 43	96 45	1,189	23
Ashland	Saunders	41 02	96 20	1,120	15
Omaha	Douglas	41 16	95 56	1,103	36
Fremont	Dodge	41 25	96 27	1,203	23
Norfolk	Madison	41 59	97 23	1,532	22
Oakdale	Antelope	42 04	97 57	1,722	18
O'Neill	Holt	42 28	98 38	1,975	16
David City	Butler	41 15	97 06	1,607	17
Columbus	Platte	41 26	97 21	1,441	13
Genoa	Nance	41 26	97 43	1,584	31
Ericson	Wheeler	41 47	98 41	2,029	11
Palmer	Merrick	41 14	98 15	1,796	.....
St. Paul	Howard	41 13	98 27	1,813	11
North Loup	Valley	41 59	97 23	1,961	18
Ord	do	41 36	98 55	2,051	12
Burwell	Garfield	41 48	99 09	2,180	20
Loup	Sherman	41 17	98 57	2,067	12
Seneca	Thomas	42 02	100 50	2,971	6
Ravenna	Buffalo	41 02	98 54	2,028	17
Ansley	Custer	41 15	99 22	2,307	15
Callaway	do	41 18	99 54	2,555	12

Rainfall stations in drainage basin of Platte River—Continued.

Station.	County.	Latitude.	Longitude.	Elevation.	Length of record.
		° ′	° ′	*Feet.*	*Years.*
Broken Bow	Custer	41 24	99 37	2,477	12
Central City	Merrick	41 04	98 00	1,708	17
Marquette	Hamilton	40 58	98 00	1,830	25
Aurora	do	40 52	98 00	1,792	13
Grand Island	Hall	40 55	98 21	1,861	15
Hastings	Adams	40 35	98 23	1,932	14
Kearney	Buffalo	40 42	99 05	2,147	17
Lexington	Dawson	40 20	98 50	2,385	17
Gothenburg	do	40 57	100 10	2,557	12
North Platte	Lincoln	41 08	100 45	2,821	32
Camp Clarke[a]	Cheyenne	41 40	103 06	3,800	9
Alliance	Boxbutte	42 05	102 51	3,968	14
Gering	Scotts Bluff	41 49	103 38	3,902	15
Lusk (Wyo.)	Converse	42 46	104 28	5,007	17
Fort Laramie (Wyo.)	Laramie	42 12	104 31	4,270	30
Alcova (Wyo.)	Natrona	42 34	106 33	5,366	8
Lander (Colo.)	Fremont	42 50	108 45	5,372	15
Rawlins (Wyo.)	Carbon	41 45	107 24	6,744	7
Laramie (Wyo.)	Albany	41 19	105 35	7,188	16
Lodgepole	Cheyenne	41 10	102 38	3,820	12
Kimball	Kimball	41 13	103 40	4,697	18
Cheyenne (Wyo.)	Laramie	41 08	104 48	6,088	36
Fort Morgan (Colo.)	Morgan	40 15	103 47	4,000	13
Greeley (Colo.)	Weld	40 25	104 44	4,637	14
Moraine (Colo.)	Larimer	40 21	105 35	7,900	16
Boulder (Colo.)	Boulder	40 02	105 16	5,400	10
Denver (Colo.)	Arapahoe	39 45	105 00	5,272	34
Castle Rock (Colo.)	Douglas	39 22	104 52		

[a] Now Bridgeport, for which place latitude, longitude, and elevation are given.

The following table gives records of precipitation at the stations named in the foregoing list:

Precipitation at stations in the drainage basin of Platte River, 1896–1906.

LINCOLN, LANCASTER COUNTY.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.66	0.92	1.37	2.62	4.38	4.23	3.82	3.26	2.04	2.03	0.68	0.75	26.80
1896	.32	.27	1.28	4.57	10.11	3.05	5.63	3.39	4.57	3.02	1.48	.37	38.06
1897	.65	.90	1.48	6.15	2.22	2.17	2.54	2.69	1.71	2.77	.29	2.10	25.67
1898	.83	.99	1.40	3.88	4.33	3.99	3.93	3.45	2.32	1.55	.95	.48	28.10
1899	.11	.56	.70	1.49	2.29	8.39	1.47	2.66	.39	2.58	.58	1.31	22.53
1900	.13	.97	.67	4.33	4.50	2.50	6.66	9.07	1.92	2.45	.03	.49	33.72
1901	.22	.79	1.73	1.46	1.96	1.42	2.94	1.02	6.00	3.62	.41	.52	22.09
1902	1.02	.14	.37	.67	3.65	8.83	11.35	4.35	4.10	2.87	1.97	1.96	41.22
1903	.25	1.30	.47	3.50	.72	2.60	3.07	6.45	1.34	2.90	1.87	.07	34.66
1904	.60	.07	.97	5.11	4.20	4.40	5.12	2.39	2.96	1.33	.28	.29	27.72
1905	.93	.85	.59	2.71	5.11	3.43	3.25	6.45	6.91	2.56	2.52	.06	35.37
1906	.49	.86	3.67	3.51	1.53	3.60	6.85	2.74	7.60	2.12	.28	.83	34.08

ASHLAND, SAUNDERS COUNTY.

Normal	0.60	0.64	1.20	2.83	4.32	4.59	4.92	4.13	2.95	2.24	0.77	0.72	29.91
1896	.21	.30	.98	2.99	10.57	1.80	5.56	2.85	5.45	3.28	1.88	.35	36.20
1897	.32	.43	1.23	7.29	2.12	2.31	1.66	1.44	3.70	3.39	.25	1.13	25.27
1898	.13	.42	1.56	1.62	2.89	3.20	5.63	1.12	5.29	2.16	.71	.28	25.01
1899	.03	.80	.45	1.50	4.34	10.65	3.54	4.31	.58	2.47	.96	1.74	30.87
1900	.10	.62	.44	3.37	2.27	3.15	6.52	6.07	2.76	4.27	T.	.68	30.25
1901	.13	.42	1.56	1.62	2.80	3.20	5.63	1.12	5.29	2.16	.71	.28	25.01
1902	1.31	.02	.40	.94	3.22	8.72	13.86	5.41	2.70	2.67	1.49	1.79	42.53
1903	T.	1.60	.50	3.80	10.67	2.30	5.92	5.77	2.84	1.75	.50	T.	35.29
1904	.50	.05	.74	4.46	5.96	2.74	3.40	3.71	2.36	1.44	.27	.30	25.93
1905	.95	.70	.56	5.17	3.77	2.54	2.73	5.54	7.46	1.75	2.52	.14	33.83
1906	.48	1.05	2.00	3.74	1.90	5.93	4.68	3.09	6.84	2.05	.40	1.94	34.10

Precipitation at stations in the drainage basin of Platte River, 1896–1906—Continued.

OMAHA, DOUGLAS COUNTY.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.69	0.79	1.50	3.13	4.37	5.67	4.75	3.34	2.91	2.47	1.06	1.01	31.69
1896	.33	.33	1.31	4.28	9.51	1.90	4.53	3.50	3.97	3.72	2.02	.50	34.90
1897	.87	.63	1.47	5.67	2.16	1.43	2.01	1.92	1.30	1.82	.14	1.79	21.30
1898	.31	.66	2.07	.89	2.13	5.31	2.98	.65	6.83	1.96	.56	.73	25.08
1899	.07	.71	.64	1.73	4.45	5.77	1.73	6.18	.53	2.26	1.38	1.29	26.74
1900	.15	.81	1.48	3.43	2.24	3.07	6.86	3.52	3.60	5.43	.15	.46	31.20
1901	.31	.66	2.07	.89	2.13	5.31	2.98	.65	6.83	1.96	.56	.73	25.08
1902	.71	.13	.70	.85	2.88	7.32	7.28	2.86	1.52	2.13	1.38	2.72	30.48
1903	.07	1.12	.58	2.01	8.32	1.31	2.67	12.50	2.50	1.19	1.01	.15	33.43
1904	.62	.10	1.32	3.20	4.86	3.11	3.15	4.45	2.60	1.40	.10	.57	25.48
1905	1.13	1.36	.70	3.43	3.40	1.70	2.36	3.03	5.94	3.97	2.72	.14	29.88
1906	.60	.71	1.75	3.67	2.50	5.30	2.85	2.03	4.84	1.56	.52	1.26	27.59

FREMONT, DODGE COUNTY.

Normal	0.92	0.87	1.66	2.90	4.47	5.06	4.36	3.87	2.81	2.31	0.92	0.98	31.13
1897	.92	.60	1.90	5.61	.86	2.68	1.23	2.27	.56	2.77	.22	2.05	21.67
1898	.40	.80	2.41	1.17	2.75	5.50	2.11	1.14	7.59	1.79	.75	.90	27.31
1899	.15	.81	.87	2.15	6.90	10.17	2.95	9.78	.61	.78	1.28	1.53	37.98
1900	.24	1.10	1.34	3.75	2.00	1.22	5.36	6.37	4.81	5.47	.13	.66	32.45
1901	.40	.80	2.41	1.17	2.75	5.50	2.11	1.14	7.59	1.79	.75	.90	27.31
1902	.85	.08	.86	1.27	2.36	6.68	7.90	2.89	2.90	2.53	1.25	2.20	31.77
1903	T.	.97	.73	2.64	10.94	3.15	4.87	11.08	2.89	2.08	1.46	.17	40.98
1904	.27	T.	.96	2.75	5.10	5.09	4.82	3.85	1.58	1.54	.20	.25	26.41
1905	1.60	.95	.93	4.48	4.80	3.93	1.83	3.45	7.63	2.59	3.22	.02	35.43
1906	.73	.90	2.07	6.18	4.63	5.62	5.11	4.66	5.80	2.61	.43	1.12	39.86

NORFOLK, MADISON COUNTY.

Normal	0.40	0.74	1.03	2.81	4.26	4.61	3.97	3.81	3.37	1.68	0.70	0.72	27.10
1896	.27	.02	.67	5.92	3.30	5.26	5.65	1.08	2.25	2.50	2.54	.15	29.61
1897	.70	.43	1.55	3.86	1.03	2.93	3.72	2.67	1.43	2.97	.26	2.10	23.65
1898	.69	.70	.72	1.49	3.53	6.04	1.60	2.01	1.46	.86	.31	.42	19.83
1899	.05	.95	.54	.48	8.30	4.41	2.16	2.98	.86	.95	.78	1.35	23.87
1900	.14	.95	1.28	4.84	2.81	2.47	4.12	3.90	4.78	3.26	.17	.17	28.89
1901	.05	.25	1.49	1.71	3.02	8.10	.67	.86	8.52	2.65	1.27	.59	29.18
1902	.91	.41	.94	1.66	3.25	7.11	8.58	5.18	3.93	1.06	.26	1.35	34.64
1903	.14	1.36	1.65	3.52	6.87	3.02	6.35	7.10	.96	2.42	1.09	.16	34.58
1904	.54	.21	.41	2.00	5.02	5.22	4.64	4.81	1.92	4.04	.12	.23	29.16
1905	.94	.72	.88	3.83	9.88	4.43	4.31	3.28	6.14	.82	2.45	T.	37.68
1906	.54	1.01	1.08	5.70	5.95	4.32	2.22	2.79	6.11	3.31	.72	1.25	35.00

OAKDALE, ANTELOPE COUNTY.

Normal	0.47	0.60	1.05	3.09	3.94	4.55	3.52	2.69	2.32	1.64	0.66	0.64	25.16
1896	.13	.05	1.14	6.94	2.51	4.50	6.17	1.12	1.76	2.39	2.66	.07	29.44
1897	1.61	.51	1.78	3.36	1.12	4.87	2.98	3.38	1.15	2.33	.64	1.44	25.17
1898	.55	.78	.69	1.88	5.75	4.82	2.15	2.92	.93	1.15	.53	.44	22.59
1899	.08	.47	.80	1.42	5.47	5.42	1.35	2.18	1.57	.88	.43	.74	20.81
1900	.13	.98	.77	5.32	3.82	2.05	4.80	3.61	3.14	2.88	.20	.10	27.87
1901	.09	.33	1.29	2.24	2.86	7.34	1.02	.80	6.83	1.78	1.05	.63	26.26
1902	.46	.25	1.23	2.07	2.56	5.29	6.29	3.28	3.74	.76	.09	1.08	27.10
1903	.06	.82	1.50	2.24	9.58	4.30	8.72	5.01	1.57	2.08	.66	.13	36.07
1904	.25	.30	.48	2.00	2.90	5.90	4.87	3.11	1.98	5.26	.15	.33	27.53
1905	.78	.58	.75	2.60	8.36	5.70	2.74	2.20	7.79	1.41	1.69	T.	34.60
1906	.47	.98	.99	4.90	2.16	3.91	1.49	3.53	5.12	3.25	.87	1.49	29.16

Precipitation at stations in the drainage basin of Platte River, 1896–1906—Continued.

O'NEILL, HOLT COUNTY.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.40	0.62	1.24	3.37	2.89	4.28	2.95	2.77	2.39	1.34	0.51	0.69	23.52
1896	.32	.04	1.36	6.86	1.77	5.87	3.85	1.56	3.41	1.84	1.37	.10	28.35
1897	1.31	.48	1.69	4.85	1.35	3.15	1.51	2.26	3.70	3.84	.13	1.86	26.13
1898	.38	.42	.75	1.39	5.62	2.82	3.87	2.33	1.29	1.25	.20	.05	20.37
1899	.18	.13	.63	1.14	3.40	4.17	4.48	4.02	.70	.33	1.02	.15	20.35
1900	T.	.95	.75	5.47	2.57	1.78	4.93	3.07	1.94	3.21	.20	.54	25.35
1901	.06	1.10	1.45	2.23	1.49	9.68	.05	1.22	7.51	1.72	.90	.91	28.32
1902	.45	.40	1.94	1.84	2.32	4.12	4.95	5.25	6.57	.61	.18	2.10	30.73
1903	.35	1.32	.59	1.30	5.26	1.33	5.04	4.44	.90	.90	1.52	.....	.....
1904	.....	.70	.14	1.83	3.31	5.33	3.80	3.19	1.66	.....	.05	.36	.....
1905	.73	.30	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

DAVID CITY, BUTLER COUNTY.

Normal	0.82	0.75	1.66	3.81	4.52	4.34	4.08	3.62	2.54	2.17	0.84	0.74	29.93
1896	.60	.25	2.70	10.25	7.60	2.80	6.90	1.45	4.25	3.30	2.60	.25	42.95
1897	.95	.50	1.75	6.60	2.65	2.00	1.90	3.30	1.10	4.10	.30	1.30	26.45
1898	.75	.50	.75	2.75	6.80	5.30	.70	2.80	2.20	1.65	.80	.40	25.40
1899	.40	.75	.45	.....	.....	6.05	4.50	6.45	1.10	2.05	1.00	1.80	.....
1900	.15	.80	1.30	6.00	3.00	1.50	5.00	9.60	4.40	3.65	.40	.35	36.15
1901	.55	1.20	3.10	2.10	2.40	4.25	2.90	1.65	5.20	1.20	T.	1.20	25.75
1902	.85	.35	.....	.....	.....	.....	.....	2.07	3.07	.....	.....	.....	.....
1903	.....	.....	.65	3.17	13.09	1.77	5.82	6.90	2.33	2.17	1.52	.02	.....
1904	.80	.05	1.33	2.90	5.68	3.27	5.20	2.22	1.81	2.47	.24	.18	26.15
1905	1.44	.86	1.56	4.77	7.88	5.02	3.03	4.86	6.29	1.44	2.36	.02	39.53
1906	.72	1.66	2.20	5.67	3.64	5.34	7.51	3.24	3.51	4.04	.61	1.11	39.25

COLUMBUS, PLATTE COUNTY.

Normal	0.32	0.58	0.96	3.07	3.70	4.05	3.30	3.55	3.14	2.01	0.69	0.55	26.40
1896	.44	T.	.48	6.78	5.50	4.42	4.12	2.32	2.37	2.25	2.23	.03	30.94
1897	.69	.66	1.90	5.10	1.12	3.15	2.67	3.11	2.22	3.85	.15	1.47	26.09
1898	.40	.48	.82	2.45	5.92	5.09	.82	3.86	2.41	1.52	.48	.11	24.36
1899	.01	.72	.87	.34	5.19	5.80	4.11	4.03	.93	.95	.60	1.12	24.61
1900	.01	.57	.71	4.65	1.97	2.34	3.61	7.40	7.95	3.99	.03	.10	33.33
1901	.12	.64	.83	1.66	1.74	3.34	1.33	.60	6.03	1.64	.78	.42	19.13
1902	.65	.14	.67	1.44	3.64	7.83	8.40	2.40	1.78	3.28	.47	.91	31.61
1903	T.	1.33	1.58	2.98	9.46	.84	6.28	8.33	2.65	.99	.90	.06	35.40
1904	.08	.02	.93	1.67	4.78	4.60	4.94	1.97	1.10	2.96	.09	.13	23.27
1905	1.16	.55	.64	3.91	8.61	3.90	2.62	2.84	6.87	1.14	2.33	.02	34.59
1906	.19	1.13	.99	3.96	3.94	2.65	3.02	3.07	3.88	3.75	.48	.94	28.00

GENOA, NANCE COUNTY.

Normal	0.71	0.74	1.21	3.03	4.35	4.40	3.95	3.03	3.14	1.77	0.78	0.80	28.01
1896	.46	.09	.56	7.57	4.09	5.47	3.27	1.41	2.40	2.03	2.41	.27	30.01
1897	1.36	.64	1.81	5.47	1.64	3.80	4.59	2.93	2.71	4.12	.34	1.44	30.85
1898	.58	.94	.82	2.78	4.58	3.91	1.36	3.98	2.02	1.13	.55	.15	22.80
1899	.07	.78	.59	1.08	5.54	4.25	1.71	4.62	.51	.87	.71	1.63	22.30
1900	.04	.58	.58	5.87	3.18	1.95	5.32	6.94	10.45	4.76	.22	.28	40.17
1901	.05	.58	1.05	2.64	1.68	4.85	.50	.61	7.65	2.89	1.30	.70	24.50
1902	.60	.40	1.04	.98	4.55	9.37	7.55	1.99	2.15	3.19	.32	.98	33.12
1903	T.	1.03	2.17	2.66	7.51	1.32	9.90	7.12	1.43	.66	1.34	T.	35.14
1904	.14	.02	.14	1.78	6.52	6.14	7.60	2.39	1.88	2.40	.11	.25	29.37
1905	.91	.69	1.34	4.39	11.45	2.44	3.64	1.15	6.12	.38	2.55	.04	35.10
1906	.49	1.01	2.06	7.17	1.99	2.65	2.20	3.45	3.98	3.20	.49	1.14	29.83

Precipitation at stations in the drainage basin of Platte River, 1896–1906—Continued.

ERICSON, WHEELER COUNTY.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.60	0.77	1.13	3.08	2.24	3.63	3.47	2.47	2.30	1.78	0.48	0.59	22.40
1896	.50	T.	1.10	6.20	2.71	4.86	4.36	2.07	2.63	1.90	.60	.25	26.73
1897	1.00	.50	2.64	4.25	2.07	3.85	1.98	2.61	.87	3.84	.10	1.50	25.21
1898	.70	.40	.20	1.38	3.92	2.48	1.91	2.68	.91	.35	.53	.20	15.66
1899	T.	.60	.80	1.85	3.91	4.95	1.70	2.49	2.56	.20	.35	1.94	19.35
1900	T.	1.30	T.	3.89	2.63	1.94	4.30	4.87	1.95	2.07	.20	9.18	23.27
1901	.10	.90	1.63	1.64	1.34	5.06	.22	.97	6.53	2.92	1.00	.48	22.79
1902	.60	.90	2.30	2.00	4.45	4.05	8.35	3.95	4.00	1.10	.20	.90	32.80
1903	.30	1.70	.25	2.40	4.25	1.60	8.00	6.60	T.	2.10	.85	.10	28.15
1904	.85	.40	.20	1.60	2.76	4.20	6.73	1.42	1.10	4.70	.30	.60	24.86
1905	2.00	1.10	1.69	4.35	7.90	6.90	2.30	.20	5.70	.60	2.40	T.	35.14
1906	1.00	.22	1.20	6.75	3.50	1.25	1.22	2.28	5.38	.....	.47	2.10	.....

PALMER, MERRICK COUNTY.

Normal	0.65	0.72	1.48	2.71	3.69	4.09	3.76	3.22	2.40	1.47	0.60	0.60	25.39
1896	0	.60	.90	7.55	6.55	4.35	2.50	.45	2.05	2.50	1.30	.35	29.10
1897	1.10	.50	3.17	4.44	2.30	4.84	2.06	3.49	2.69	4.68	.08	2.00	31.35
1898	.40	.50	.85	1.98	3.38	8.12	.97	3.65	3.18	.66	.35	T.	24.04
1899	T.	.75	.....	.40	3.99	4.45	2.79	3.29	.52	.12	.50	1.00	.....
1900	T.	.65	.90	4.60	2.55	3.78	5.25	3.90	5.00	2.58	.10	.27	29.58
1901	.10	.70	1.90	2.35	.52	2.62	1.50	1.50	7.11	2.77	.70	.35	22.12
1902	.60	.20	1.50	.51	4.65	8.24	4.20	4.68	4.93	3.00	.35	.70	33.56
1903	.20	1.30	.66	2.25	8.85	1.95	7.53	11.55	1.46	.80	.85	.20	37.60
1904	.40	.10	.45	1.85	2.90	5.60	9.18	2.45	1.85	3.20	.30	.04	28.32
1905	1.30	.60	1.11	3.94	8.93	6.46	9.20	4.95	6.17	.20	1.80	.10	44.76
1906	.30	.40	2.00	8.02	1.80	6.65	3.95	2.50	3.20	3.20	T.	1.10	33.12

ST. PAUL, HOWARD COUNTY.

Normal	0.43	0.62	1.12	3.08	3.96	5.38	4.94	3.63	2.80	2.12	0.75	0.46	29.30
1896	.21	.05	.97	7.23	4.57	5.53	3.95	1.05	2.96	2.37	2.04	.10	31.04
1897	.96	.72	1.89	4.59	.50	5.06	1.75	3.23	1.41	5.35	.17	1.20	26.83
1898	.56	.56	.54	2.27	3.45	7.16	1.38	3.80	2.96	.45	.52	.12	23.77
1899	.16	.56	.61	.60	2.77	5.32	4.73	5.55	.74	.78	.71	1.26	23.79
1900	.04	.84	.26	3.75	1.51	4.38	5.19	4.01	3.55	2.82	.16	.34	26.85
1901	.13	.85	2.14	2.54	.86	4.17	.84	1.14	5.71	2.45	1.04	.23	22.10
1902	.70	.49	1.88	.65	5.65	10.30	5.54	5.38	3.87	3.26	.20	.83	38.75
1903	.11	1.32	1.70	2.16	7.44	3.06	6.85	10.04	.52	.79	1.01	.06	35.06
1904	.24	T.	.30	1.89	1.95	4.01	9.00	1.59	2.60	2.87	.10	.09	24.64
1905	1.14	.86	1.02	4.15	7.70	8.41	7.47	3.49	5.26	.96	1.74	T.	42.20
1906	.46	.53	1.38	6.17	5.01	1.93	3.68	2.24	2.39	3.08	.55	1.33	28.75

NORTH LOUP, VALLEY COUNTY.

Normal	0.66	0.62	1.08	3.22	3.21	4.58	4.07	2.70	2.14	1.77	0.58	0.50	25.12
1896	.24	T.	.83	7.25	3.44	8.00	4.32	.55	2.44	2.18	1.12	T.	30.37
1897	.80	.36	1.42	6.05	.72	7.87	1.19	2.54	1.00	4.65	.10	1.40	28.10
1898	.55	.40	.20	1.00	3.65	4.43	.99	1.97	1.78	.53	.70	.30	16.50
1899	.60	.50	.74	1.75	2.87	5.58	1.18	3.50	.89	.20	.65	1.52	19.92
1900	.02	1.60	.87	5.26	2.66	3.63	5.76	4.00	2.11	2.36	.25	.50	28.96
1901	.05	1.05	2.18	2.68	2.32	4.79	1.86	1.64	5.84	2.76	1.07	.36	26.60
1902	.80	.55	2.38	1.58	5.06	4.89	6.75	4.36	4.22	2.24	T.	.53	33.36
1903	.30	1.40	1.10	1.95	6.22	2.38	6.46	5.06	.71	1.17	.85	T.	27.60
1904	.17	.13	.63	1.19	3.15	2.81	4.74	1.08	2.85	4.92	.05	.05	21.77
1905	1.25	.79	1.28	4.59	7.04	10.17	8.80	2.10	4.23	.42	1.63	T.	42.30
1906	.67	.40	.69	6.41	1.33	1.46	4.61	3.98	3.12	2.82	1.09	1.32	27.90

Precipitation at stations in the drainage basin of Platte River, 1896–1906—Continued.

ORD, VALLEY COUNTY.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.32	0.59	0.96	3.36	3.21	4.26	3.60	3.13	2.76	2.20	0.64	0.45	25.38
1896	.21	T.	1.29	4.37	2.38	8.37	2.74	.32	1.96	2.91	.99	T.	25.54
1897	.41	.42	1.57	4.63	1.05	4.90	1.71	3.33	.96	4.36	.10	.87	24.31
1898	.60	.34	.22	2.04	3.43	2.31	.91	2.04	2.75	.56	.27	.43	15.95
1899	T.	.33	.75	1.21	2.62	3.60	.84	2.03	.63	.20	.93	.56	13.70
1900	.03	1.40	.29	4.59	1.53	6.56	3.18	5.74	1.57	2.65	.13	.21	27.88
1901	.09	.81	2.29	3.03	2.30	5.52	1.76	1.31	5.92	2.61	.88	.55	27.07
1902	.....	.28	2.18	1.19	5.89	2.55	6.52	5.33	4.09	1.45	0	.99	.....
1903	.22	1.21	.26	1.84	5.52	2.14	8.19	4.21	.06	1.57	.35	0	25.57
1904	.18	0	.27	1.72	2.76	3.54	5.68	.84	1.80	4.80	0	.05	21.64
1905	1.45	.76	1.11	4.70	6.20	6.78	5.48	2.51	4.98	.80	1.10	0	35.87
1906	.32	.97	.99	7.95	1.64	.57	2.62	6.75	6.21	3.94	1.37	1.65	34.98

BURWELL, GARFIELD COUNTY.

Normal	0.49	0.74	0.98	2.65	2.46	4.41	3.53	2.96	1.96	1.58	0.41	0.50	22.57
1896	.35	.10	1.85	3.85	1.71	4.70	3.77	1.47	.92	1.29	.70	T.	20.71
1897	.50	.40	1.60	3.24	.60	2.44	1.87	1.41	T.	3.89	.20	1.55	17.70
1898	1.00	.30	T.	1.68	3.14	2.68	2.33	4.68	.86	.56	.30	.65	18.18
1899	T.	.60	.05	.42	2.97	3.93	1.27	3.26	.54	0	.66	.95	14.65
1900	T.	1.55	.31	5.39	.85	5.85	4.69	3.87	1.38	1.96	.25	T.	26.10
1901	.10	1.15	1.87	2.89	1.78	8.63	.87	2.05	9.08	1.76	.73	.95	31.80
1902	.60	.35	1.75	2.13	4.45	5.32	5.73	3.89	5.01	.87	.15	.95	31.14
1903	.20	1.70	.15	2.17	7.07	.96	7.36	5.18	.08	1.54	.20	.20	26.87
1904	.95	.10	.60	2.03	3.30	9.79	6.69	2.88	2.87	5.51	.05	T.	34.77
1905	1.30	1.20	.40	4.56	5.73	6.14	4.22	.17	5.87	.65	1.21	T.	31.45
1906	.50	.30	1.23	5.21	.....	3.10	1.95	3.25	3.50	4.45	1.35	.45	.....

LOUP, SHERMAN COUNTY.

Normal	0.23	0.38	1.05	3.47	3.64	6.08	5.32	3.98	3.36	2.36	0.61	0.48	30.95
1896	.26	T.	1.14	7.11	3.93	11.78	3.86	.80	2.98	1.82	.64	T.	34.42
1897	.42	.43	1.32	4.80	.65	7.17	.78	7.75	2.97	5.75	.25	1.35	23.64
1898	.50	.08	.03	2.48	2.30	3.91	1.93	2.74	3.23	.42	.40	T.	18.02
1899	T.	T.	.44	1.24	2.47	8.20	3.36	3.11	1.36	0	.66	1.00	21.84
1900	T.	.53	.44	4.20	2.13	4.14	8.51	4.11	2.81	2.57	.20	.17	29.81
1901	.25	.55	2.49	2.45	1.49	6.47	1.54	2.54	7.67	3.96	.95	.31	30.67
1902	.35	.45	2.37	.93	5.85	6.46	8.86	5.03	4.80	3.50	.17	1.00	39.77
1903	.20	.70	1.67	1.18	9.79	2.13	9.24	6.06	1.20	1.98	1.21	0	35.36
1904	T.	T.	.14	3.02	4.19	5.79	10.04	2.70	3.89	4.69	T.	.20	34.66
1905	.45	.40	.94	4.18	5.55	10.32	4.15	8.47	4.88	.73	1.55	0	41.62
1906	.25	.50	.60	6.55	1.60	.51	6.29	3.00	2.30	2.61	1.26	1.65	27.12

SENECA, THOMAS COUNTY.

Normal	0.28	0.39	0.65	2.34	.....	2.07	2.83	1.28	0.84	0.30	0.17	0.32	.....
1896	.20	.20	1.40	5.75	1.00	2.00	4.39	.20	1.48	.20	.40	.24	18.15
1897	.55	.40	1.59	3.93	.50	5.70	4.54	1.80	.89	.70	T.	1.20	21.80
1898	.52	0	.10	.50	8.25	.20	5.00	2.55	1.70	0	.15	.15	19.12
1899	.20	.20	.10	.....	.15	.80	.28	.25	0	0	.44	.62	.....
1900	T.	.75	.10	2.80	3.40	.55	4.25	.23	0	T.	T.	T.	12.08
1901	.05	.70	.65	.57	.15	.65	.52	.....	1.16	.....	0	.05	.....
1902	.50	.32	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1903	.....	1.10	.50	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1904	.....	.....	.....	.....	.....	.....	3.38	3.17	1.25	1.53	.01	T.	.....
1905	1.50	.....	.41	2.96	.....	3.27	.....	.04	.....	.....	.....	.....	.....

Precipitation at stations in the drainage basin of Platte River, 1896–1906—Continued.

RAVENNA, BUFFALO COUNTY.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.65	0.88	1.67	2.72	3.58	3.85	4.02	3.23	2.23	1.78	0.62	0.64	25.67
1896	.35	.12	1.67	5.72	4.58	2.66	5.37	.89	3.25	1.45	1.30	.14	27.50
1897	.60	.88	1.61	5.21	1.94	5.82	1.73	6.54	1.63	4.96	.30	1.53	32.75
1898	.33	2.68	.23	2.23	3.15	3.25	2.19	1.72	3.10	.56	.69	.37	18.50
1899	.05	.89	.90	.86	1.93	8.91	2.11	5.33	45	.58	.94	1.14	24.09
1900	.01	1.40	.37	3.56	2.25	1.90	4.36	1.74	2.43	3.17	.30	.25	21.74
1901	.25	.90	3.42	2.71	1.39	3.63	2.37	2.88	6.76	1.67	.84	.33	27.15
1902	.80	.70	1.51	.46	6.82	3.89	8.96	3.42	5.35	3.95	.17	1.03	37.06
1903	.37	2.55	1.50	1.45	6.73	3.94	9.58	7.62	.51	1.87	.74	.03	36.89
1904	.16	.02	.80	2.05	2.50	2.79	7.48	4.50	2.34	4.47	.12	.14	27.45
1905	1.25	.98	.88	3.97	6.94	4.67	2.61	4.65	4.49	1.10	1.65	T.	33.28
1906	.51	.82	1.52	6.39	2.27	2.12	4.00	4.57	2.35	2.70	.85	1.60	29.70

ANSLEY, CUSTER COUNTY.

Normal	0.38	0.84	1.25	2.77	3.35	4.01	3.68	2.94	1.74	1.66	0.40	0.44	23.46
1896	.63	.03	1.95	4.66	3.52	2.92	1.85	.64	2.25	1.75	.80	.02	21.32
1897	.40	.47	1.46	5.00	1.54	4.57	.92	4.55	1.47	4.98	.35	1.52	27.13
1898	.35	.45	.10	2.69	3.87	3.49	1.42	2.12	1.64	1.08	.45	.20	17.86
1899	.04	.85	.55	2.20	2.12	5.67	4.86	3.23	.95	.44	.89	.99	22.79
1900	T.	1.25	.48	4.55	1.76	.88	3.82	5.24	2.91	1.27	.20	.57	22.93
1901	.30	1.50	3.46	2.93	1.45	8.08	.....	2.35	4.10	2.32	.52	.29	.....
1902	.52	.57	.88	1.03	4.41	4.08	5.64	3.12	3.19	2.24	T.	1.10	26.78
1903	.62	1.65	.41	1.20	9.64	2.90	6.45	6.61	.60	.83	.60	T.	31.51
1904	.14	.12	.40	1.84	5.83	3.95	6.60	4.33	2.40	3.98	.10	.15	29.84
1905	1.40	1.00	1.15	8.41	6.85	5.74	2.77	.....	.....	.....	.....	.....	.....

CALLAWAY, CUSTER COUNTY.

Normal	0.38	0.62	0.89	3.03	3.09	4.12	2.83	3.40	1.92	1.43	0.59	0.38	22.68
1896	.25	.05	1.33	5.69	1.53	3.58	1.93	1.95	2.20	1.00	.70	T.	19.71
1897	.35	.48	1.28	5.30	.30	4.95	.70	1.79	1.15	5.00	.30	.95	22.54
1898	.45	.15	.60	2.35	4.45	2.98	2.60	6.85	1.50	T.	.65	T.	22.58
1899	T.	.55	T.	.55	2.21	5.65	1.40	1.85	.75	.45	1.65	.63	15.69
1900	T.	1.57	.47	4.50	2.90	.95	3.50	4.70	1.90	1.25	.50	.35	22.59
1901	.17	1.01	3.13	3.35	2.15	8.30	1.33	3.85	6.65	1.90	1.15	.67	33.66
1902	.70	.35	1.30	.90	6.25	3.95	4.40	1.35	3.95	.95	.10	.95	25.15
1903	.45	1.53	.10	2.05	5.45	2.25	7.70	4.28	.30	1.10	.55	T.	25.76
1904	.64	T.	T.	.51	4.24	2.97	6.32	5.89	1.83	.....	.....	T.	.....
1905	1.35	.50	.61	3.50	7.70	6.21	3.10	.....	.....	.66	1.02	T.	.....
1906	.50	.34	1.00	8.88	1.06	1.32	2.50	3.72	4.17	4.73	1.10	.96	30.28

BROKEN BOW, CUSTER COUNTY.

Normal	0.17	0.47	0.89	3.84	3.45	4.62	4.16	2.96	2.26	2.05	0.57	0.33	25.87
1896	.07	.01	2.45	6.10	2.73	4.89	2.73	.....	2.14	2.35	.30	.20	.....
1897	.10	.55	1.60	5.40	.37	4.28	1.11	1.36	1.14	4.03	.40	1.15	21.49
1898	.70	.10	0	2.54	4.71	2.49	2.03	3.55	1.38	3.90	.22	T.	21.95
1899	T.	.22	.32	1.30	3.08	4.47	6.42	2.82	.60	.42	1.64	.66	21.95
1900	.05	1.13	.51	6.17	2.46	1.29	4.35	4.00	1.32	1.10	.32	T.	22.60
1901	.10	.50	1.88	2.45	1.71	9.26	1.15	1.03	4.83	1.60	.75	.10	25.36
1902	.32	.32	.76	1.11	5.59	2.76	6.98	2.75	3.93	1.41	0	.72	26.65
1903	.24	1.15	.35	.81	5.40	2.32	6.27	6.16	.50	.98	.40	T.	24.58
1904	.10	T.	.20	1.47	5.06	3.73	6.50	1.97	3.66	3.92	T.	T.	26.61
1905	.93	1.10	1.10	5.59	5.73	8.26	5.41	.94	3.14	1.13	.71	0	34.04
1906	55	.22	.62	9.35	2.23	1.77	5.89	4.06	2.55	3.75	1.60	1.03	33.62

Precipitation at stations in the drainage basin of Platte River, 1896–1906—Continued.

CENTRAL CITY, MERRICK COUNTY.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.44	0.73	1.20	2.99	3.95	4.10	4.52	2.45	2.43	2.11	0.64	0.64	26.20
1896	.28	.02	1.30	9.55	5.80	4.72	3.20	1.12	2.37	2.40	2.10	.14	31.00
1897	.91	.60	1.35	6.10	1.75	3.75	2.38	2.07	2.96	3.97	.70	1.10	27.64
1898	.50	.30	.22	2.20	5.25	5.15	.40	2.30	2.07	.70	.31	.25	19.65
1899	T.	.75	.10	1.25	5.12	6.73	3.44	2.21	1.02	0	.98	1.35	22.95
1900	T.	.86	.60	5.43	2.05	3.71	3.70	3.96	6.26	5.65	T.	.20	32.42
1901	.50	1.00	2.40	3.10	.25	1.75	3.40	2.62	5.68	3.02	1.37	.....	.....
1902	.60	.05	1.10	.92	5.63	7.51	10.16	4.63	3.29	3.52	.45	.80	38.66
1903	T.	1.55	1.72	1.55	13.57	3.04	8.88	4.87	1.04	1.10	.72	.30	38.28
1904	.35	T.	.60	2.40	1.24	5.08	5.48	1.71	.35	3.61	.20	T.	21.02
1905	1.90	.50	.....	4.11	7.64	5.95	5.79	6.29	7.08	.78	2.14	T.	.....
1906	.95	1.50	2.65	10.13	4.88	6.43	4.31	2.14	2.24	3.74	.57	1.02	40.56

MARQUETTE, HAMILTON COUNTY.

Normal	0.60	0.73	1.04	2.94	3.98	4.38	4.13	2.92	2.49	2.27	0.70	0.63	27.83
1896	.20	.22	1.06	7.30	7.15	4.24	5.29	.90	2.22	2.76	1.65	.12	33.11
1897	1.53	.77	1.93	4.48	2.48	3.40	1.82	1.72	1.83	4.79	.75	1.45	26.95
1898	.47	.50	.50	2.12	3.85	6.46	.62	1.74	2.44	1.10	.90	.32	21.02
1899	.20	.35	.27	.65	4.37	4.08	2.99	2.56	1.16	.....	.84	1.26	.....
1900	T.	.55	.64	5.96	2.47	4.11	3.95	4.08	5.51	6.63	.15	.73	34.78
1901	.25	.80	2.50	2.45	.84	2.32	2.39	1.00	5.89	2.53	1.08	.36	22.41
1902	.70	.74	1.14	.87	5.14	7.57	11.05	3.17	4.35	4.46	.39	.95	40.53
1903	.15	1.45	1.18	1.63	10.65	2.14	6.44	7.39	1.60	1.74	1.00	T.	35.37
1904	.20	.04	.40	2.41	1.59	5.42	5.46	3.02	1.90	4.08	.20	.30	25.02
1905	1.15	.88	.76	5.50	6.51	7.32	5.59	6.32	7.11	1.10	2.19	.05	24.48
1906	.41	.62	1.65	6.57	2.58	4.20	4.71	1.76	3.41	3.65	.36	1.25	32.17

AURORA, HAMILTON COUNTY.

Normal	0.25	0.74	1.09	3.20	4.16	4.65	3.83	3.64	3.28	2.36	0.70	0.49	28.39
1896	.29	.07	.69	.98	5.68	3.40	5.81	2.06	3.10	2.82	1.70	T.	35.60
1897	.62	.80	2.31	3.79	2.09	5.35	1.07	2.95	2.07	5.58	.20	1.90	28.72
1898	.30	.70	.74	1.67	3.73	8.45	.69	1.84	3.02	1.53	.38	.32	23.37
1899	.05	.75	.20	1.08	3.53	4.66	.....	2.63	.90	1.00	.79	1.34	.....
1900	.03	1.32	.69	6.70	2.71	1.53	3.60	6.26	6.15	3.09	.13	.01	32.82
1901	.10	.82	2.18	2.62	.70	2.16	1.79	4.69	7.28	2.35	.84	.29	25.82
1902	.60	.87	1.42	1.76	5.95	6.85	5.96	2.08	5.68	4.96	.33	.80	32.26
1903	.10	.....	1.11	2.29	12.03	3.10	4.90	7.54	.69	1.80	1.30	.00	.....
1904	.17	T.	.45	3.03	1.55	3.65	3.82	5.83	3.00	4.10	.05	.02	25.73
1905	.70	.68	.35	4.33	4.94	5.29	6.53	3.56	5.35	.91	3.00	.10	35.74

GRAND ISLAND, HALL COUNTY.

Normal	0.47	0.78	1.31	3.36	4.65	4.66	4.00	3.56	2.61	2.69	0.78	0.73	29.60
1896	.14	.22	1.42	9.38	7.60	3.94	3.76	1.31	2.40	2.76	1.52	.14	34.56
1897	.70	.69	2.54	7.01	1.59	5.34	2.40	2.40	2.15	6.28	.65	1.71	33.46
1898	.35	.73	.77	2.81	4.28	4.73	1.39	3.47	3.72	1.32	.75	.44	24.76
1899	.12	.08	.99	1.00	4.99	7.02	2.48	3.78	.53	1.11	1.08	1.59	25.37
1900	0	1.05	.68	6.03	.84	4.18	4.02	4.23	1.18	5.88	.22	.41	32.32
1901	.17	.98	2.77	3.13	1.04	2.88	1.62	2.73	8.35	2.23	1.00	.29	27.19
1902	.77	.48	1.17	1.16	5.47	5.59	10.26	2.56	4.62	4.18	.22	1.07	38.55
1903	.20	2.09	1.39	1.86	12.27	3.11	9.31	6.25	1.27	1.79	1.29	.01	40.84
1904	.20	.01	.64	1.00	1.51	4.98	5.25	6.83	1.66	5.52	.20	.28	28.99
1905	1.64	1.55	.73	4.01	9.53	8.97	6.48	3.66	5.67	1.21	2.40	0	45.85
1906	.50	1.10	.....	4.88	4.02	3.94	5.50	3.43	2.39	3.26	.28	1.10	.....

Precipitation at stations in the drainage basin of Platte River, 1896–1906—Continued.

HASTINGS, ADAMS COUNTY.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.42	1.11	1.22	3.46	4.00	4.45	3.83	3.41	2.66	2.25	0.66	0.52	27.99
1896	.30	T.	1.69	9.26	6.13	4.20	3.50	2.42	2.52	2.70	1.36	T.	34.00
1897	.27	.85	1.58	4.89	2.82	6.23	3.89	2.91	2.33	5.82	.60	1.39	33.58
1898	.30	.33	.25	4.26	3.75	3.00	.55	6.55	3.65	1.82	.39	.24	25.09
1899	.04	1.25	1.02	1.00	2.26	4.55	2.20	3.57	.86	.46	.64	1.02	18.87
1900	T.	1.30	.52	5.74	2.01	3.88	5.66	2.29	4.11	2.18	.04	.01	27.74
1901	.06	0	.95	3.47	1.25	5.49	3.25	1.33	6.87	1.60	.73	.28	22.88
1902	.72	.59	1.29	.42	7.57	6.74	10.62	2.39	3.80	3.87	.20	.80	39.01
1903	.20	2.50	.45	1.45	10.92	3.35	5.06	9.86	.60	1.31	1.12	T.	36.82
1904	.15	.05	.66	3.25	1.64	5.57	3.46	1.84	1.87	4.11	.12	.18	22.90
1905	1.25	1.50	.91	4.06	7.50	7.51	3.27	1.92	6.03	.60	2.35	.05	36.95
1906	.48	1.51	3.02	3.52	2.20	2.50	3.19	2.09	1.73	2.28	.15	.80	23.47

KEARNEY, BUFFALO COUNTY.

Normal	0.51	0.89	1.00	2.92	4.65	4.10	4.66	3.11	2.88	1.99	0.60	0.48	27.54
1896	.32	T.	2.10	4.96	6.90	3.26	3.49	3.49	1.98	1.25	1.55	.54	29.82
1897	.32	.99	1.08	6.52	1.18	3.29	4.01	1.60	2.51	5.70	.82	1.68	29.70
1898	.17	.25	.04	3.60	4.11	4.18	1.76	2.53	3.40	.65	.45	.10	21.24
1899	0	.60	.60	.25	4.77	7.93	4.90	5.10	.85	.45	1.20	1.00	27.65
1900	T.	.65	.40	4.92	2.03	1.70	3.32	2.94	2.10	3.70	T.	T.	21.76
1901	.10	.32	2.15	4.00	1.64	3.15	2.05	4.17	6.32	1.30	.82	.10	26.12
1902	.75	.60	2.09	.66	5.42	4.71	8.66	2.57	4.98	4.13	.03	.55	35.15
1903	.22	2.25	1.21	1.78	8.64	4.63	8.40	7.19	.52	1.04	.58	.02	36.48
1904	.21	.01	.14	2.51	2.78	6.69	4.73	3.54	2.01	3.86	3.19	.11	26.78
1905	.98	.87	.88	3.85	8.69	8.17	5.22	2.29	5.88	.78	1.45	0	39.06
1906	.72	.36	1.18	5.84	3.86	1.30	5.05	5.02	4.27	2.76	.....	.....	.....

LEXINGTON, DAWSON COUNTY.

Normal	0.64	0.93	1.28	2.62	3.17	3.73	3.19	3.06	2.44	1.48	0.56	0.68	23.78
1896	.38	.20	2.06	4.66	3.90	1.97	2.27	1.69	3.02	1.10	.28	.20	21.73
1897	.20	.81	1.59	4.24	.30	4.61	.72	1.57	1.60	4.13	.72	1.30	21.79
1898	.30	.30	.10	2.23	2.62	4.36	1.29	2.51	2.92	.73	.80	.35	18.51
1899	.05	1.25	1.40	.47	2.66	4.12	4.06	2.39	.65	.11	1.23	.95	19.34
1900	T.	1.55	.60	4.03	2.70	.94	3.56	2.51	2.71	.65	.20	.47	19.92
1901	.20	1.00	3.53	3.14	1.18	7.27	.87	2.99	5.64	1.55	.41	.65	28.43
1902	1.00	.80	.86	.72	5.72	2.98	6.28	3.39	2.64	3.66	.15	1.04	29.24
1903	.35	1.55	.83	1.15	5.80	3.18	9.24	5.42	.81	.88	.72	0	29.93
1904	.39	.15	.75	1.24	5.50	6.30	6.52	6.02	3.05	3.05	.05	.40	33.42
1905	1.20	1.00	.78	4.19	4.05	6.34	2.84	4.59	2.86	1.14	.60	0	29.59
1906	.50	.46	2.30	6.11	.97	1.25	2.04	4.37	2.25	3.26	.82	1.58	25.91

GOTHENBURG, DAWSON COUNTY.

Normal	0.47	0.99	0.97	2.75	3.36	4.55	2.87	3.39	2.15	1.63	0.73	0.40	24.26
1896	.36	.....	.....	6.81	2.21	3.06	2.39	1.55	1.84	1.85	1.05	T.	.....
1897	.44	.70	1.06	4.85	.55	4.45	.70	3.10	1.71	4.67	.70	1.50	24.43
1898	1.20	.40	.50	1.09	3.60	4.02	1.48	2.52	3.01	1.03	.90	.11	19.86
1899	.20	1.00	.50	.41	4.01	2.16	1.80	1.93	.60	.50	2.20	.60	15.91
1900	T.	1.70	.82	4.43	3.12	1.54	2.94	5.53	1.15	.35	.03	.30	21.91
1901	.40	.90	2.70	4.31	.....	7.57	.40	3.58	5.50	.84	.58	.25	.....
1902	.80	.85	1.88	.85	6.83	2.71	4.86	2.01	3.97	3.01	.04	1.10	28.90
1903	.40	2.20	.44	.92	3.93	3.38	6.59	5.09	.33	.55	.60	0	24.43
1904	.18	.05	.38	.65	4.23	8.68	5.16	5.10	3.44	2.85	.12	T.	30.84
1905	1.05	1.40	.88	3.11	4.94	8.60	4.84	2.54	2.38	.91	.95	0	31.60
1906	.37	.60	1.35	3.97	1.29	1.40	2.88	4.05	1.62	3.36	1.25	1.15	23.29

Precipitation at stations in the drainage basin of Platte River, 1896–1906—Continued.

NORTH PLATTE, LINCOLN COUNTY.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.47	0.42	0.75	2.17	2.70	3.42	2.74	2.42	1.28	0.98	0.35	0.57	18.27
1896	.27	.06	.87	3.44	1.47	2.76	1.86	2.07	1.87	1.51	.16	.21	16.56
1897	.47	.46	.66	2.59	.11	1.72	1.85	3.05	.59	4.11	.85	.63	17.09
1898	.77	.19	.64	1.42	4.12	2.54	1.29	1.40	2.56	.07	.51	.03	15.54
1899	.11	.36	.83	.82	3.58	1.95	2.04	1.83	.28	.28	1.59	.32	13.99
1900	.06	.78	.26	3.34	.90	1.42	3.37	1.37	.25	.39	.09	.06	12.29
1901	.04	.44	1.53	2.53	1.83	3.69	.34	2.00	3.14	.41	.30	.19	16.44
1902	.40	.35	1.42	.92	7.98	3.46	4.56	1.74	3.34	1.34	T.	.78	26.27
1903	.27	1.29	.12	.95	3.74	3.99	2.93	3.58	.76	.44	.38	.01	18.36
1904	.32	.06	.52	1.52	3.63	4.43	4.90	3.25	2.40	1.92	.03	.19	23.17
1905	.90	.69	2.15	3.78	4.56	7.63	2.58	1.57	1.23	1.05	.67	T.	26.81
1906	.61	.80	2.22	2.89	2.82	.68	3.14	5.56	4.25	3.05	1.01	.96	27.99

CAMP CLARKE, CHEYENNE COUNTY.[a]

Normal	0.47	0.62	1.05	2.19	2.97	2.13	2.40	1.99	1.20	0.71	0.28	0.47	16.39
1898	1.20	T.	.75	1.07	4.22	1.68	2.13	1.01	.30	.07	.85	.35	13.63
1899	.80	.80	1.40	.53	2.75	1.53	2.26	2.12	T.	.24	.30	.15	13.38
1900	T.	1.20	.25	5.84	1.21	1.56	1.64	.84	.82	.58	.08	.68	14.70
1901	T.	1.20	1.25	3.54	2.63	2.06	1.31	2.21	2.70	.32	T.	1.18	18.40
1902	.30	.50	1.33	1.00	2.93	5.10	3.31	2.93	3.32	1.01	T.	.80	22.56
1903	.30	.77	.47	.55	1.76	1.00	1.93	3.15	1.23	.80	.11	T.	12.07
1904	.30	.05	T.	.67	2.74	2.40	2.56	.70	1.00	.32	T.	.20	10.94
1905	1.30	1.10	.81	4.74	5.59	2.72	3.87	1.65	1.24	.43	.22	0	23.67
1906	T.	T.	3.20	1.75	2.87	2.28	1.22	1.42	.98	2.50	.55	.20	16.97

ALLIANCE, BOXBUTTE COUNTY.

Normal	0.60	0.09	0.90	2.05	2.84	2.87	2.60	1.81	0.82	0.64	0.35	0.38	16.35
1896	.60	.69	2.10	.80	2.00	4.04	3.77	.26	1.41	.70	.39	0	16.11
1897	.43	.21	1.21	2.13	2.52	2.01	1.73	2.15	.06	.36	.64	1.10	14.55
1898	1.14	T.	.30	.53	4.81	1.10	4.76	.20	T.	T.	.60	0	13.44
1899	.43	.55	.88	.75	3.45	1.30	1.85	1.70	0	.50	T.	.25	11.66
1900	T.	1.15	.10	3.08	2.10	.45	2.70	1.05	1.00	.40	T.	.25	12.28
1901	T.	.70	.95	1.40	3.90	2.80	.20	1.70	.70	1.10	T.	.90	14.35
1902	.60	.50	1.41	2.30	1.20	4.45	1.60	2.00	2.55	.....	.....	1.55	.....
1903	.05	.....	.....	.82	2.60	1.40	4.45	3.35	1.21	.10	.05	.25	.....
1904	.18	.07	T.	1.00	2.36	4.28	3.27	1.80	1.37	.....	.0	T.	.....
1905	.80	.10	.10	3.83	5.34	3.69	4.74	.....	.....	.....	.30	T.	.....
1906	.15	T.	1.30	3.70	2.81	3.88	1.01	3.75	1.32	3.30	.95	.70	22.87

GERING, SCOTTS BLUFF COUNTY.

Normal	0.46	0.59	0.82	1.73	2.49	2.55	1.98	1.28	1.01	0.68	0.39	0.54	14.52
1896	.40	.36	1.50	.66	2.42	3.44	1.90	1.31	1.89	.33	.48	.....	14.69
1897	.19	.30	1.08	1.40	1.79	.67	2.76	1.96	.30	.10	.68	.40	11.63
1898	.....	.....	.30	1.80	4.90	1.38	1.65	.60	.28	.57	1.10	.....	.....
1899	.....	1.04	1.92	.41	7.72	1.77	1.90	2.24	.19	1.19	.10	.13	.....
1900	T.	1.78	.26	4.16	.67	.55	4.14	.67	1.50	1.01	.08	.37	15.19
1901	T.	.75	.76	2.31	1.75	4.01	1.20	1.64	2.32	.98	T.	1.54	17.26
1902	.15	.74	1.26	1.29	2.44	3.63	1.71	1.00	4.12	.66	.12	1.13	18.25
1903	.30	.89	.48	1.42	1.71	1.95	1.48	.....	.....	.....	.....	.05	.....
1904	.18	.25	.32	1.38	2.61	2.12	2.15	.54	.90	.73	.01	.11	11.30
1905	1.17	.65	.69	4.41	4.57	4.53	2.87	1.62	1.63	1.22	.14	T.	23.00
1906	T.	.12	2.05	2.80	3.95	3.33	1.42	.....	.....	.....	.....	.....	.....

[a] Record since 1902 obtained at Bridgeport.

Precipitation at stations in the drainage basin of Platte River, 1896–1906—Continued.

LUSK, CONVERSE COUNTY, WYO.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.53	0.55	1.22	1.45	2.56	2.54	1.66	1.03	0.67	0.65	0.32	0.40	13.58
1896									1.97	.87	.88	T.	
1897	.59	T.	1.61	1.01	.87	.79	1.05	2.32	.23	.21	.65	.24	10.07
1898	.70	.46	.92	1.02	4.17	2.09	.67	.51	.72	.54	.57	.78	13.15
1899	1.30	1.35	2.25	.25	4.22	2.76	.57	1.01	.67	2.42	.06	.26	17.12
1900	0	.15	0	3.46	.34	1.15	2.74	.06	1.21	.23	0		
1901	0	.60	1.06		2.98	3.70	.05	.95	.20	1.46	.08	1.10	
1902	.22	.80	.98	1.65	1.80	3.05	1.69	.45	.57	.70	T.	1.32	13.23
1903	.38	1.38	1.10	1.66	2.27	2.12	5.65	.57	1.15	0	.26	.38	16.92
1904	.20	.12	.53	1.22	2.71	5.83	.34	.05	.62	0	0	.30	11.89
1905	1.05	.77	.22	.77	4.40	2.82	3.01	3.08	0	.20	.35	.20	16.87
1906	.65	.42	2.70	.30	4.49	2.17	.61	4.35	1.85	1.20	.65	.40	19.79

FORT LARAMIE, LARAMIE COUNTY, WYO.

Normal	0.46	0.41	0.71	1.69	2.19	1.55	1.48	0.95	0.95	0.70	0.32	0.45	11.86
1896	1.29	.61	1.14	.97	2.63	2.34	1.41	1.00	1.75	.83	.73	0	14.69
1897	.29	.38	2.17	1.03	1.23	2.03	.99	2.06	1.14	1.02	.63	.78	13.75
1898	1.41	.26	.25	.75	4.60	1.29	1.61	1.13	.44	.44	.55	.25	12.96
1899	.85	.95	1.73	.91	4.29	1.94	1.84	1.38	.53	2.69	.12	.14	17.37
1900	0	.90	.30	7.48	.45	1.31	3.69	.34	2.12	.42	.24	.70	17.95
1901	T	.85	2.11	3.48	4.29	3.43	1.62	.57	.38	.31	.16	.12	18.32
1902	.19	.10	1.81	1.70	3.61	3.80	.71	T.	2.10	.60	.14	.68	15.44
1903	.02	.76	1.31	1.53	1.48	1.03	.92	2.73	1.57	.26	.57	.18	12.36
1904	.05	.22	.60	1.06	3.63	2.57	1.09	.13	1.19	.73	.05	.21	11.53
1905	1.22	.81	.49	4.91	3.72	2.32	3.19	1.49	1.10	1.32	.24	T.	20.81
1906	T.	.30	1.87	1.05	3.18	2.46	1.98	2.02	3.08	1.75	.94	.48	19.11

ALCOVA, NATRONA COUNTY, WYO.

Normal	0.44	0.13	0.81	1.34	2.00	0.97	1.31	0.50	1.00	0.86	0.11	0.62	10.09
1899	.70	.13			2.09	1.38	.60	.10	1.20	1.07	T.	.32	
1900	.07	.68	T.	3.01	.50	T.	1.85	T.	.94	.70	T.	.63	8.38
1901	.10	.91	.20	1.03	1.57	2.20	1.27	.35	T.	1.45	.50	1.37	11.95
1902	.41	T.	.57	.52	2.39	.90	1.35	.23	.78	.27	.08	1.07	8.57
1903	.92	.30	.62	1.22	1.42	1.53	.94	.62	1.59	1.37	T.	.20	8.73
1904	.27	.17	.87	.47	2.84	1.43	.36	.64	.57	1.90	0	.11	9.63
1905	.83	.27	.42	1.51	1.66	.65	1.71	.32	1.58	T.			
1906	.22	.11	1.99	1.64	3.57	.70	2.43	1.70	1.31	1.09	.20		

LANDER, FREMONT COUNTY, COLO.

Normal	0.33	0.76	1.61	2.70	2.24	1.17	0.93	0.64	0.86	0.99	0.65	0.78	13.67
1896	.25	.20	1.62	1.60	2.13	.60	1.67	1.19	.93	.46	.42	0	11.07
1897	.23	1.11	1.38	1.14	1.25	.85	1.21	1.04	.15	1.12	.44	1.29	11.21
1898	.33	T.	2.73	1.08	6.02	3.02	.67	.62	.36	2.22	.25	.69	17.99
1899	.88	.57	1.65	.49	2.15	.82	.46	.08	.54	1.57	T.	.94	10.15
1900	T.	1.06	.31	7.19	.51	.39	.51	.25	2.05	.73	.33	.90	14.23
1901	.16	.94	.38	3.11	3.13	1.87	T.	.58	.13	.43	.22	1.87	12.82
1902	.18	.20	.79	1.43	1.23	.93	.29	.06	.75	1.10	.06	.25	7.25
1903	.25	.82	2.25	2.41	1.86	1.99	.21	.19	2.58	.57	.01	.94	14.08
1904	.56	.63	1.57	1.05	4.49	2.20	1.31	.24	.41	1.87	.01	.49	14.86
1905	.23	.24	1.07	2.55	3.13	.88	.47	.57	1.11	1.52	1.82	.55	14.14
1906	.63	.25	3.56	2.29	3.49	.14	1.01	1.26	.67	2.04	.41	.92	16.67

Precipitation at stations in the drainage basin of Platte River, 1896–1906—Continued.

RAWLINS, CARBON COUNTY, WYO.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.71	1.07	1.52	1.40	1.45	1.30	1.27	0.46	1.09	0.83	0.70	1.05	12.48
1898	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.60	.80	.....
1899	1.16	1.40	3.01	1.16	1.20	2.17	1.96	.43	.99	.64	.91	.93	15.96
1900	.13	1.02	.56	2.89	.17	.11	1.97	.07	.94	.28	.71	.30	9.15
1901	.25	2.07	1.67	.90	2.76	1.06	.46	.55	.11	.93	.25	.86	12.88
1902	.67	.49	1.19	.95	.89	1.10	.80	.10	1.85	1.75	.23	2.11	12.13
1903	1.33	.95	1.42	1.96	1.78	1.05	1.26	1.01	1.56	.55	.49	.29	13.65
1904	.....	.47	1.21	.52	1.91	2.33	1.28	.....	.....	.....	.....	.....	.....
1905	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1906	.42	.05	1.00	1.06	1.78	.....	.....	.95	.67	.90	.45	.57	.....

LARAMIE, ALBANY COUNTY, WYO.

Normal	0.26	0.32	0.88	1.18	1.44	1.16	1.37	1.01	1.02	0.83	0.25	0.32	10.04
1896	.44	.17	.59	3.53	2.37	2.72	.66	.89	1.16	.18	.09	T.	13.80
1897	.39	.35	4.23	.55	1.85	.72	1.29	1.11	.32	.55	.33	.77	12.46
1898	.05	.01	.40	1.26	1.88	.90	.65	1.16	T.	.48	.61	.23	7.63
1899	.95	1.13	1.11	1.75	.37	1.11	2.01	1.44	.17	1.13	.07	.61	11.85
1900	.01	.82	.58	2.91	.24	.35	1.25	.61	1.11	.61	.06	.03	8.58
1901	.04	.41	.05	.28	3.00	1.73	.32	1.11	.09	1.28	T.	.31	8.52
1902	T.	.26	.41	.80	.26	.60	1.49	.40	1.58	.74	.22	.89	7.65
1903	.11	.36	1.09	.73	1.63	1.00	1.31	.88	2.39	.50	.30	.07	10.37
1904	.25	.11	.36	.84	1.74	2.01	1.33	.93	1.35	.54	.04	.08	9.58
1905	.39	.42	.64	1.21	1.79	.36	1.79	.83	1.64	.53	.22	.03	9.85
1906	.58	.05	1.01	1.75	.91	1.71	1.75	.59	2.09	1.33	.41	.39	12.57

LODGEPOLE, CHEYENNE COUNTY.

Normal	0.34	0.66	1.05	1.78	2.12	2.04	2.32	1.83	0.91	0.51	0.17	0.52	14.11
1896	.20	.50	2.80	1.73	2.94	3.29	3.01	.96	1.32	.60	.50	T.	17.85
1897	.15	.40	2.25	2.10	3.38	1.42	2.15	3.61	T.	1.50	.20	.60	17.76
1898	.40	.10	.10	.10	3.55	T.	1.60	.....	2.25	.10	.70	.50	.....
1899	1.50	.70	.80	1.10	1.25	1.40	2.65	.55	0	T.	T.	.32	10.27
1900	T.	.90	T.	6.07	2.37	1.80	3.00	.....	T.	T.	.10	.30	.....
1901	T.	.80	2.80	2.50	3.50	3.70	.75	3.00	1.25	.25	T.	1.10	19.65
1902	.50	.30	.....	.75	1.20	.....	2.37	1.27	.....	.....	.....	1.70	.....
1903	T.	1.80	.52	.97	T.	.84	2.90	2.80	.55	T.	T.	.80	10.46
1904	T.	.20	T.	1.05	1.40	2.00	3.47	2.25	2.50	1.85	T.	.....	.....
1905	.60	.30	1.45	3.62	4.70	2.00	8.07	1.90	2.45	.....	.....	.....	.....
1906	.....	.....	.....	.....	.....	1.65	1.20	2.55	2.10	.....	.....	.30	.....

KIMBALL, KIMBALL COUNTY.

Normal	0.47	0.73	1.02	2.15	2.67	2.14	2.59	1.31	0.95	0.59	0.41	0.56	15.50
1896	.40	.66	1.02	1.75	2.26	1.48	2.43	2.22	1.66	.20	.30	0	14.38
1897	.20	.75	1.70	1.10	3.86	2.16	6.42	1.66	.44	.88	.60	1.15	20.92
1898	.65	.15	.75	1.32	6.49	2.61	2.26	.45	.60	.65	1.60	.55	18.08
1899	.65	.50	.68	.65	3.67	1.06	2.70	1.42	0	.58	T.	.30	12.21
1900	T.	1.30	.25	7.62	.77	.40	2.17	.27	1.56	.14	.20	.25	14.93
1901	T.	1.43	1.90	2.40	1.17	4.29	2.04	.72	1.38	.63	.05	1.55	17.56
1902	.20	.75	1.20	1.05	1.94	1.59	2.65	2.04	3.41	.25	.20	2.05	17.33
1903	.15	1.00	.50	1.25	1.56	1.38	3.66	2.69	1.05	.25	.15	T.	13.64
1904	.05	.49	.13	1.65	3.64	2.09	2.68	.61	1.08	.57	.15	.15	13.29
1905	.65	1.20	1.87	5.57	4.04	4.10	3.48	2.38	1.57	.73	T.	0	25.59
1906	.15	.20	2.00	2.52	3.86	1.88	2.36	2.06	1.01	1.86	.....	.....	.....

Precipitation at stations in the drainage basin of Platte River, 1896–1906—Continued.

CHEYENNE, LARAMIE COUNTY, WYO.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal.....	0.37	0.40	0.70	1.39	2.25	1.53	1.79	1.56	0.88	0.72	0.33	0.28	12.20
1896.....	.68	.31	2.06	2.08	2.85	1.41	6.35	2.52	2.08	.28	.14	.03	20.79
1897.....	.27	.57	2.32	.60	3.07	1.60	3.77	1.66	.41	1.03	.68	1.27	17.25
1898.....	.48	.06	.39	.68	3.72	2.33	11.83	.90	.47	.25	1.58	.36	13.05
1899.....	1.23	1.63	1.89	.97	1.70	.74	3.28	1.15	.07	1.27	.07	.18	14.18
1900.....	.15	1.25	.72	7.66	.76	1.01	1.20	.70	2.19	.03	.09	.33	16.09
1901.....	.13	1.10	1.54	2.97	2.47	1.93	1.34	.83	.75	.31	T.	1.62	14.99
1902.....	.21	.55	2.11	1.49	2.51	1.55	1.49	.53	3.52	.52	.23	1.79	16.50
1903.....	.20	1.76	1.00	2.10	.46	1.42	.79	1.90	1.40	.34	.79	.09	12.25
1904.....	.35	.33	.45	1.80	6.66	1.78	2.00	.87	.83	.57	.02	.06	15.72
1905.....	.84	.69	1.27	6.45	4.04	1.90	2.97	1.93	1.06	1.40	.11	.02	22.68
1906.....	.21	.21	2.27	3.10	1.30	2.42	1.89	.49	1.86	2.33	1.42	.15	17.65

FORT MORGAN, MORGAN COUNTY, COLO.

Normal.....	0.15	0.85	0.49	1.97	1.86	1.38	1.70	1.47	0.83	0.69	0.29	0.25	11.39
1897.....	.....	.10	1.51	.06	1.47	3.28	.....	5.36	.....	1.96	.36	.19	.....
1898.....	0	.01	.02	.81	4.33	1.30	2.49	.33	.43	.71	.40	.11	10.94
1899.....	.56	.22	.47	.50	1.82	.07	2.77	.84	.....	.....	.....	.....	.....
1900.....	.....	.57	.62	9.98	1.06	.94	1.52	1.07	.55	0	T.	.11	.....
1901.....	.05	.39	1.07	4.10	.....	.....	T.	.96	.73	.....	.....	.27	.....
1902.....	T.	T.	.....	.....	.....	1.46	1.14	2.41	3.91	1.04	.40	.51	.....
1903.....	T.	.45	.27	.54	.88	2.85	2.22	.44	.65	.06	.23	.15	8.74
1904.....	.02	.58	.20	1.65	3.01	1.05	2.70	1.56	1.44	.40	.05	.10	12.76
1905.....	.38	.10	.....	.....	.....	.....	.....	.....	.....	1.62	T.	0	.....
1906.....	T.	.03	.....	2.09	2.38	.....	.....	.....	.79	2.21	.56	T.	.....

GREELEY, WELD COUNTY, COLO.

Normal.....	0.22	0.42	0.67	1.89	2.40	1.36	1.81	0.92	0.87	0.77	0.49	0.26	12.10
1896.....	.67	.18	.93	1.18	1.42	.46	4.82	2.15	.99	.63	.02	.07	13.52
1897.....	.06	.61	2.02	.81	3.20	2.47	2.98	1.75	.29	1.11	.40	.38	16.09
1898.....	.20	.33	.23	1.46	5.83	1.69	3.50	.83	.13	.78	.60	.37	15.95
1899.....	1.14	.69	.71	.70	1.15	.47	2.34	1.04	.30	1.85	T.	.40	10.79
1900.....	.16	.58	.62	6.22	.96	.31	1.28	T.	1.07	.11	.04	.16	11.51
1901.....	.22	.45	.95	2.12	2.38	2.45	.26	.47	1.06	.75	.05	1.06	12.22
1902.....	.12	.16	.16	.80	1.77	.62	.65	.48	4.13	.54	.73	.67	10.83
1903.....	.02	.68	.47	.56	.96	1.76	1.25	.93	.72	.51	.30	T.	8.16
1904.....	T.	.20	.38	1.70	3.66	1.74	3.77	.49	1.25	.46	T.	.04	13.69
1905.....	.17	.15	1.62	4.08	5.35	.55	1.81	.60	.17	1.47	.03	.00	16.00
1906.....	T.	.01	3.06	3.04	1.91	1.10	2.24	.70	.....	2.50	.93	.03	.....

MORAINE, LARIMER COUNTY, COLO.

Normal.....	0.59	1.28	1.62	2.26	2.50	1.34	1.95	1.62	1.25	1.21	0.62	0.63	16.87
1896.....	.53	.22	2.87	1.08	.62	.49	3.88	2.50	2.74	.75	.30	.30	17.28
1897.....	.61	1.68	1.86	1.29	2.30	1.79	2.52	2.43	.78	1.16	1.25	1.20	18.87
1898.....	.50	1.05	1.32	1.44	3.05	1.93	2.19	1.67	.40	.99	1.77	.55	16.86
1899.....	.77	2.32	2.98	1.39	.45	1.57	3.02	1.32	.15	1.96	0	.65	16.58
1900.....	.21	1.11	.30	7.74	1.30	.91	.36	.23	2.19	1.42	.47	.48	16.72
1901.....	.61	.72	1.06	2.36	3.32	1.52	1.43	2.65	.42	.38	.27	1.15	15.89
1902.....	.25	.04	1.39	.70	1.15	.55	1.45	.80	3.70	.30	.68	.73	11.74
1903.....	.12	.95	1.06	1.42	.20	3.25	1.05	.90	2.40	1.83	.64	.01	13.83
1904.....	T.	1.33	1.14	.40	5.66	1.80	.96	2.30	.....	.....	.....	.....	.....
1905.....	.....	1.17	1.97	7.10	1.14	.....	1.41	.21	.40	3.45	.05	.00	.....
1906.....	.55	.25	4.57	2.63	2.03	1.15	2.82	1.49	2.16	1.77	1.54	T.	20.96

Precipitation at stations in the drainage basin of Platte River, 1896–1906—Continued.

BOULDER, BOULDER COUNTY, COLO.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.40	0.74	1.65	3.11	2.88	1.84	1.54	1.22	1.54	1.49	0.50	0.75	17.66
1897					2.30	3.71	3.09	2.96	.86	1.66	.47	.70	
1898	.43	.55	.67	1.54	3.76	1.51	.97	1.52	1.12	.90	1.76	1.30	16.03
1899	.87	.98	2.79	1.23	.55	.58	2.18	1.87	.15	1.94	T.	.96	14.04
1900	.40	1.06	.75	9.18	1.84	.49	.48	.22	1.54	.13	.19	.61	16.89
1901	.53	.30	1.74	3.51	1.62	1.76	.46	1.69	.16	.65	T.	1.43	13.85
1902	.37	.48	1.48	1.01	2.32	1.46	1.26	.53	5.46	1.44	1.29	1.34	118.44
1903	.08	1.52	1.45	2.31	2.02	1.87	.95	1.46	1.31	3.43	.15	.16	16.71
1904	.09	.31	2.37	1.45	5.35	2.72	1.05	1.00	1.60	1.06	.08	.70	17.78
1905	.81	.70	1.85	6.65	4.78	.55	1.86	.22	1.64	2.54	.23	T.	21.83
1906	.22	.17	2.45	5.32	3.37	1.56	3.81	2.50	3.13	1.80	1.87	T.	26.20

DENVER, ARAPAHOE COUNTY, COLO.

Normal	0.56	0.52	0.96	2.04	2.83	1.40	1.71	1.49	0.78	0.91	0.63	0.66	14.49
1896	.25	.24	1.43	.93	1.27	.89	2.80	.97	1.87	.84	.10	.31	11.84
1897	.58	.82	.90	1.31	3.15	2.16	2.06	1.44	.44	1.64	.24	.63	15.37
1898	.20	.68	.28	1.20	4.88	.94	.67	.96	.28	1.05	.85	.99	12.98
1899	.65	.58	1.10	.75	.15	.47	1.92	1.78	.20	1.01	T.	.72	9.33
1900	.13	.55	.63	8.24	.53	1.87	1.30	.50	.87	.33	.37	.42	15.29
1901	.05	.06	.88	1.96	1.18	2.09	.01	1.30	.22	.46	T.	.89	9.10
1902	.17	.38	.63	.60	1.98	1.89	1.24	.76	3.70	.80	.61	.39	13.35
1903	.12	.42	.87	.81	.75	1.62	1.36	1.35	.56	1.34	.07	.23	9.50
1904	.04	.17	.94	.74	3.27	3.54	2.13	.60	1.77	.40	.04	.41	14.05
1905	.99	.35	3.07	4.95	2.65	.61	1.55	.67	.49	2.31	.04	T.	17.68
1906	.17	.06	1.88	3.67	1.45	1.51	1.21	.88	2.72	1.98	1.30	.01	16.84

CASTLE ROCK, DOUGLAS COUNTY, COLO.

Normal	0.49	0.79	1.08	2.14	2.60	2.12	2.77	2.34	0.91	1.22	0.50	0.72	17.68
1896	.65	.95	1.80	2.30	1.61	.70	3.67	3.57	2.80	1.62	.32	.45	20.44
1897	.47	1.20	2.50	1.37	2.44	3.12	3.59	8.10	.24	2.82	.57	1.23	27.56
1898	.63	.94	.40	1.76	4.48	1.82	4.20	1.49	1.35	1.17	1.00	.99	20.23
1899	.63	.67	.77	1.50	.53	1.10	4.48	2.39	T.	1.30	.17	1.16	14.70
1900	.10	.63	.62	7.90	.55	1.80	1.77	.24	.06	.40	.33	.30	14.70
1901	.25	.30	1.04	3.47	1.82	1.35	1.72	3.45	.50	.28	T.	.59	14.77
1902	.11	.39	1.09	1.10	2.70	1.50	1.46	1.29	3.17	.80	.70	1.36	15.67
1903	.62	1.32	.70	1.04	1.29	3.25	1.53	1.17	.98	1.25	.15	.47	13.77
1904	.16	.48	1.07	.73	5.94	4.97	3.60	2.95					
1905									.70			.05	
1906	.13	.10	2.03	4.30	.95	1.94	.35	.63	2.34	3.53	.51	0	16.87

KANSAS RIVER DRAINAGE BASIN.

DESCRIPTION OF BASIN.

The drainage basin of Kansas River lies south of that of the Platte, and includes two important streams and their tributaries in southern Nebraska, namely, Republican and Big Blue rivers.

Republican River rises in the eastern part of Colorado, flows eastward through the southern tier of counties in Nebraska to the town of Superior, where it bends southward, and unites with the Smoky Hill to form the Kansas at Junction City, Kans. Its drainage area, therefore, includes portions of Colorado, Kansas, and Nebraska.

The headwater region of the river is a comparatively high tableland, cut by canyons and dotted with hills and buttes. Throughout

Nebraska the drainage area is gently rolling or level, and most of the western part, except the immediate stream valley, is given over to cattle raising. The soil of the valley is very fertile and large quantities of alfalfa, hay, and grains are grown.

Rainfall over the area varies from 18 to 27 inches annually, and evaporation from 4½ feet in the eastern part to 5 feet in the western part. During the spring months the river is subject to excessive floods, many of which have caused considerable damage, particularly in Kansas. At some points in the western part of the area the entire flow of the stream is diverted for irrigation.

The principal tributaries of the Republican in Nebraska are Beaver Creek, Red Willow Creek, Frenchman River, and South Fork of the Republican.

Kansas River as such is a comparatively short stream. Its most important feeder below the junction of Smoky Hill and Republican rivers is the Big Blue, which rises in southeastern Nebraska, flows to the southeast and south into Kansas, and joins Kansas River at Manhattan. The principal tributary of the Big Blue is the Little Blue, which rises in southern Nebraska, flows southeastward, and unites with the main stream near Blue Rapids, Kans.

Gaging stations have been maintained in this basin in Nebraska at the following points:

Gaging stations in Republican River basin.

River.	Station.	County.	Established.	Discontinued.
Republican	Benkelman	Dundy	Nov. 1, 1894	(a)
Do	Bostwick	Nuckolls	June 6, 1904	
Do	Superior	do	June 20, 1906	Nov. 30, 1903
South Fork Republican	Benkelman	Dundy	Nov. 1, 1894	(a)
Frenchman	Wauneta	Chase	Aug. 8, 1895	Nov. 26, 1896
Do	Palisade	Hitchcock	Oct. 14, 1894	Nov. 28, 1896

a Observations suspended during the years 1896 to 1902, inclusive.

REPUBLICAN RIVER AT BENKELMAN.

The station established on November 1, 1894, at Benkelman was discontinued September 7, 1895. It was reestablished May 20, 1903, at a point some distance below the first station. Its present location is about one-half mile east of Benkelman, on the line between secs. 17 and 20, T. 1 N., R. 37 W., one-fourth mile above the mouth of the South Fork.

At the gaging section the channel is nearly straight. The bed is composed of shifting sand, and the banks are low but seldom overflow. The channel is slightly obstructed by the piling of the bridge, against which considerable débris lodges at times of high water. The current is never sluggish, even at low stages. It is impossible to obtain records of winter flow. The range of gage heights is about 4 feet.

Measurements are made from the upstream side of a pile bridge, the hand rail being marked at 5-foot intervals.

The gage is a vertical staff, 6 feet long, spiked to the downstream side of the second bent from the left end of the bridge. It is referred to bench marks as follows: (1) The top of the south end of the concrete foundation for the west upright bent of the elevated track in the Burlington and Missouri River Railroad yards; elevation, 16.14 feet above the zero of the gage. (2) The top of the upstream end of the first bent from the left end of the bridge; elevation, 6.88 feet above the zero of the gage.

Discharge measurements of Republican River at Benkelman, 1894–1906.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
1894.		*Feet.*	*Sec.-ft.*	1905.		*Feet.*	*Sec.-ft.*
December 9	O. V. P. Stout	1.74	75	March 21	H. C. Gardner	1.20	171
				May 2	do	1.35	156
1895.				June 6	do	1.25	61
March 23	do	1.89	72	July 5	do	1.10	36
June 4	do	1.68	141	July 31	G. W. Bates	1.40	160
June 24	do	1.06	36	August 28	H. C. Gardner	.80	10
August 7	do	.96	64	September 28	F. S. Dobson	1.10	49
1903.				1906.			
May 20	J. C. Stevens	1.15	57	May 11	do	1.15	114
September 7	do	.80	33	June 19	Arthur Dobson	1.00	40
				August 25	do	1.12	64
1904.				September 22	do	1.15	74
April 3	do	1.10	112	November 30	do	1.10	122
April 18	Adna Dobson	1.02	32				
June 16	J. C. Stevens	1.10	87				
December 7	Jas. A. Green	1.50	136				

Mean daily gage height, in feet, of Republican River at Benkelman, 1894–1906.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1894.			1894.			1894.			1894.		
1	1.72	1.92	9	1.72	1.80	17	2.04	1.85	25	1.73	1.87
2	1.72	1.91	10	1.73	1.84	18	1.77	1.85	26	1.73	2.07
3	1.72	1.90	11	1.72	2.80	19	1.77	1.82	27	1.75	1.97
4	1.72	1.85	12	1.72	2.75	20	1.75	1.81	28	1.84	1.97
5	1.73	1.80	13	1.71	2.70	21	1.72	1.75	29	1.95	1.97
6	1.76	1.83	14	1.71	2.65	22	1.72	1.80	30	1.93	1.97
7	1.75	1.80	15	1.72	2.00	23	1.72	1.95	31		1.97
8	1.74	1.82	16	2.01	1.90	24	1.73	1.92			

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1895.												
1	2.00	2.60	2.30	1.78	1.70	2.52	2.35	1.17				
2	2.50	2.60	1.92	1.78	1.63	2.30	1.80	1.10				
3	2.58	2.60	1.85	1.77	1.60	1.80	1.17	1.10				
4	2.60	2.60	1.60	1.80	1.60	1.68	1.17	1.04				
5	2.65	2.60	1.65	1.85	1.60	1.70	1.04	1.01				
6	2.65	2.65	1.70	1.95	1.54	1.65	1.04	.97				
7	2.65	2.65	1.78	2.00	1.50	1.62	.91	.96				
8	2.65	2.65	1.76	1.95	1.50	1.58	.91	.92				
9	2.68	2.65	1.80	1.95	1.46	1.60	.94	.66				
10	2.65	2.65	1.80	1.90	1.40	1.65	1.10	.61				
11	2.65	2.65	1.80	1.85	1.36	3.70	1.17	.60				
12	2.65	2.65	1.75	1.80	1.34	3.00	1.17	.61				
13	2.65	2.65	1.75	1.78	1.33	2.50	1.17	.60				
14	2.65	2.65	2.10	1.70	1.30	1.60	2.00	.92				
15	2.70	2.65	2.20	1.76	1.25	1.50	1.14	.83				

Mean daily gage height, in feet, of Republican River at Benkelman, 1894–1906—Cont'd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1895.												
16	2.76	2.65	2.30	1.78	1.25	1.50	1.11	0.72	.....	.....	.....	.....
17	2.76	2.80	2.35	1.80	1.20	1.45	.91	.71	.....	.....	.....	.....
18	2.76	2.80	2.30	1.82	1.20	1.60	.88	.60	.....	.....	.....	.....
19	2.76	2.80	2.30	.74	1.21	1.40	.86	.57	.....	.....	.....	.....
20	2.76	3.00	2.10	1.76	1.20	1.20	.91	.73	.....	.....	.....	.....
21	2.76	3.05	2.00	1.78	1.25	1.20	1.17	.42	.....	.....	.....	.....
22	2.70	3.14	1.90	1.75	1.30	1.20	1.42	.60	.....	.....	.....	.....
23	2.70	3.15	1.92	1.70	1.30	1.08	1.29	.96	.....	.....	.....	.....
24	2.65	3.30	1.91	1.64	1.35	1.08	1.23	.60	.....	.....	.....	.....
25	2.60	3.25	1.90	1.64	1.30	1.09	1.23	.57	.....	.....	.....	.....
26	.....	3.15	1.90	1.63	1.30	1.08	1.10	.55	.....	.....	.....	.....
27	2.60	2.94	1.89	2.02	1.25	1.05	1.08	.38	.....	.....	.....	.....
28	2.60	2.63	1.85	1.95	1.22	1.05	1.04	.33	.....	.....	.....	.....
29	2.60	.....	1.83	1.90	1.22	1.08	1.01	.32	.....	.....	.....	.....
30	2.60	.....	1.80	1.75	2.00	1.08	.97	.42	.....	.....	.....	.....
31	2.60	.....	1.75	.....	2.20	.....	1.01	.17	.....	.....	.....	.....
1903.												
1	.....	.....	.....	.....	.....	1.15	.90	1.22	0.60	1.00	1.10	1.10
2	.....	.....	.....	.....	.....	1.20	.85	1.00	.60	1.05	1.10	1.15
3	.....	.....	.....	.....	.....	1.20	.75	.90	.60	1.00	1.15	1.10
4	.....	.....	.....	.....	.....	1.20	.95	.90	.60	1.00	1.10	1.00
5	.....	.....	.....	.....	.....	1.20	1.00	.80	.65	1.05	1.10	1.10
6	.....	.....	.....	.....	.....	1.20	.80	.70	.85	1.00	1.10	1.35
7	.....	.....	.....	.....	.....	1.50	.75	.70	.85	1.00	1.15	1.05
8	.....	.....	.....	.....	.....	1.45	.70	.70	.80	1.00	1.10	1.25
9	.....	.....	.....	.....	.....	1.35	.70	.70	.80	1.05	1.10	1.25
10	.....	.....	.....	.....	.....	1.30	.75	.80	.90	1.05	1.10	1.25
11	.....	.....	.....	.....	.....	1.35	1.98	.70	.90	1.05	1.05	1.05
12	.....	.....	.....	.....	.....	1.30	1.20	.75	.90	1.05	1.10	1.35
13	.....	.....	.....	.....	.....	1.30	.90	.75	.90	1.00	1.10	1.25
14	.....	.....	.....	.....	.....	1.30	.80	.70	.90	1.05	1.15	1.50
15	.....	.....	.....	.....	.....	1.25	1.10	.70	.90	1.00	1.10	1.50
16	.....	.....	.....	.....	.....	1.25	1.25	.70	.95	.95	1.15	1.50
17	.....	.....	.....	.....	.....	1.20	1.00	.90	.90	1.00	1.20	1.50
18	.....	.....	.....	.....	.....	1.20	1.00	.90	.95	1.00	1.15	1.60
19	.....	.....	.....	.....	.....	1.10	1.00	.85	.95	1.00	1.15	1.70
20	.....	.....	.....	.....	1.15	1.10	1.10	.85	.95	1.05	1.25	1.60
21	.....	.....	.....	.....	1.15	1.10	1.00	.80	1.00	1.05	1.60	1.70
22	.....	.....	.....	.....	1.00	1.00	.90	.75	1.00	1.05	1.60	1.50
23	.....	.....	.....	.....	1.00	1.00	.90	.75	1.00	1.05	1.20	1.50
24	.....	.....	.....	.....	1.05	1.00	.85	.75	1.00	1.05	1.10	1.40
25	.....	.....	.....	.....	1.00	1.00	.70	.70	1.00	1.00	1.15	1.40
26	.....	.....	.....	.....	1.25	1.05	.70	.75	.95	1.00	1.20	1.30
27	.....	.....	.....	.....	1.35	1.00	.65	.85	1.00	1.05	1.20	1.60
28	.....	.....	.....	.....	1.30	1.00	.60	.75	1.00	1.05	1.20	1.50
29	.....	.....	.....	.....	1.25	1.00	.60	.75	1.00	1.05	1.10	1.50
30	.....	.....	.....	.....	1.20	.95	.60	.70	1.00	1.10	1.05	1.40
31	.....	.....	.....	.....	1.25	.....	.65	.70	.....	1.10	.....	1.40
1904.												
1	1.30	.....	1.00	1.10	1.25	1.00	1.10	1.60	.80	1.15	1.20	1.20
2	1.40	.....	.95	1.10	1.30	1.10	1.15	1.40	.70	1.15	1.20	1.30
3	1.35	.....	1.10	1.10	1.10	1.25	1.10	1.00	.80	1.30	1.20	1.20
4	1.30	.....	.90	1.10	1.25	1.60	1.20	1.20	.70	1.70	1.20	.....
5	1.30	.....	.90	1.10	1.20	1.05	1.10	1.10	.70	1.00	1.20	.....
6	1.40	.....	1.05	1.10	1.20	1.10	1.05	.....	.75	1.00	1.20	.....
7	1.50	.....	.90	1.20	1.20	1.00	1.75	.....	.80	1.00	1.20	1.50
8	1.60	.....	.95	.....	1.00	1.00	.....	1.10	.90	1.00	1.15	.....
9	1.60	.....	1.10	1.10	1.00	1.10	1.25	1.05	.90	1.00	.....	.....
10	1.60	.....	1.05	1.05	1.05	1.40	1.20	1.00	.90	1.10	1.15	.....
11	1.50	.....	1.00	1.10	1.00	1.20	1.10	.90	.90	1.10	1.15	.....
12	1.45	.....	1.00	1.00	.95	1.20	1.00	1.10	.85	1.00	1.15	.....
13	1.30	.....	1.05	1.00	.90	1.40	1.00	.80	.85	1.05	1.20	.....
14	1.45	.....	1.00	1.00	.90	1.20	.90	.80	.85	1.00	1.15	.....
15	1.55	.....	1.10	1.00	1.05	1.20	1.00	.80	.80	1.05	1.25	.....
16	1.45	.....	1.00	1.05	1.00	1.10	.90	.80	.....	1.00	1.15	.....
17	1.45	.....	1.00	1.00	1.00	1.35	.85	.80	.90	1.05	1.20	.....
18	1.45	.....	.80	1.00	1.00	1.35	.80	.80	.85	.....	1.15	.....
19	1.30	.....	.95	1.00	1.00	1.10	.90	.90	.85	1.60	1.15	.....
20	1.30	.....	1.00	1.00	1.00	1.00	1.20	.90	.85	1.30	1.20	.....

Mean daily gage height, in feet, of Republican River at Benkelman, 1894–1906—Cont'd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.												
21	0.90		1.05	1.00	1.05	1.10	1.00		0.85	1.30	1.15	
22	.90		1.00	1.05	1.10	1.15	1.00	0.90	.85	1.20	1.20	
23	1.00		1.05	1.00	1.20	1.25	.90	.85	.85	1.20	1.30	
24			1.05		1.00	1.80	1.10	.80	.85	1.15	1.20	
25			1.05	1.20	1.00	1.20	.90	.80	.90	1.20	1.15	
26			1.00	1.20	1.00	1.15	.80	.80	.90	1.10	1.20	
27			1.05	1.10	1.05	1.15	.80	.80	.90	1.20	1.25	
28		0.95	1.00	1.05	1.10	1.10	.80	.80		1.20		
29		.95	1.05	1.00	1.00	1.15	.80	.80	1.10	1.20		
30			1.10	1.30	1.00	1.15	.75	.80	1.10	1.20	1.30	
31			1.10		1.00		.75	.80		1.20		
1905.												
1				1.45	1.3	1.4	1.3	1.2	.8	1.2		
2				1.5	1.25	1.35	1.4	1.1		1.2		
3				1.35	1.3	1.25	1.25	1.2	.8	1.2		
4				1.2	1.3	1.2	1.15	1.15		1.2		
5				1.3	1.3	1.25	1.1	1.05		1.2		
6				1.25	1.3	1.2	1.1	1.2	1.05	1.2		
7				1.25	1.3	1.15	1.1	1.1	1.1	1.2		
8				1.3	1.4	1.1	1.18	1.05	1.05	1.15		
9				1.3	1.4	1.15	1.25	1.05	1.3	1.1		
10				1.35	1.4	1.3	1.25	1.05	1.3	1.2		
11				1.3	1.3	1.4	1.25	1.15	1.2	1.2		
12				1.3	1.3	1.35	1.1	1.25	1.1	1.2		
13				1.3	1.3	1.35	1.1	1.15	1.2	1.2		
14				1.3	1.25	1.2	1.05	1.05	1.2	1.2		
15				1.3	1.25	1.2	1.0	1.05	1.1	1.3		
16				1.3	1.25	1.25	1.0	1.05	1.2	1.2		
17				1.25	1.25	1.45	1.1	1.0	1.1	1.2		
18				1.25	1.3	1.35	1.05	1.0	1.2	1.2		
19			1.4	1.25	1.4	1.25	1.0	.95	1.3	1.2		
20			1.35	1.3	1.3	1.2	1.1	.95	1.3	1.2		
21			1.2	1.35	1.35	1.2	1.15	.95	1.2	1.25		
22			1.0	1.3	1.3	1.4	1.2	.95	1.2	1.3		
23			1.1	1.52	1.3	1.2	1.15	.8	1.2	1.25		
24			1.1	1.75	1.45	1.2	1.15	.8	1.1	1.25		
25			1.05	1.5	1.45	1.15	1.1	.8	1.2	1.25		
26			1.15	1.4	1.4	1.2	1.1	.85	1.2	1.25		
27			1.2	1.3	1.4	1.2	1.1	.95	1.2	1.3		
28			1.2	1.35	1.4	1.15	1.35	.8	1.2	1.35		
29			1.1	1.4	1.6	1.15	1.35	.8	1.1	1.45		
30			1.0	1.35	1.5	1.15	1.8	.78	1.1	1.55		
31			1.25		1.4		1.3	.75		1.6		
1906.												
1				1.15	1.20	1.10	.80	.90	.85	1.05	1.20	
2				1.10	1.10	1.05	.85	.90	.90	1.05	1.30	
3				1.10	1.10	1.05	.85	.90	.90	1.05	1.30	
4				1.10	1.05	1.05		.90	1.00	1.05	1.25	
5				1.10	1.20	1.00	.80	1.00	.95	1.00		
6				1.05	1.20	.95	.80	1.10	.90	1.00	1.25	
7				1.10	1.10	.90	.95	1.00	.90	1.05	1.20	
8				1.10	1.25	.85	1.05	1.00	.85	1.05	1.20	
9				1.10	1.25	.80	1.05	1.00	.85	1.05		
10				1.10	1.15	.80	1.05	1.00	.85	1.05	1.20	
11					1.15	.80	1.00	1.00		1.10	1.20	
12					1.10	.80	1.00	1.00	.90	1.10	1.20	
13				1.10	1.10	.80		1.00	.90			
14				1.15	1.10	.85	.80	.90			1.25	
15				1.15	1.05	1.70	.80	.90		1.05	1.25	
16				1.15	1.05		.80	.90	.90	1.15	1.25	
17					1.00	1.05	.80	.90	.95	1.20	1.30	
18				1.20	1.00	1.00	.75	.80	1.00	1.05	1.20	
19				1.20		1.00	.70	.80	1.00	1.10		
20				1.20		.85	.70	.80	1.10	1.10		
21				1.20	1.05	.80	.60	.80	1.10			
22				1.20	1.05		.50	.70	1.10			
23				1.15		1.00	.50		1.10		1.30	
24				1.20	1.70	1.00	.70	1.10	1.10		1.30	
25				1.15	1.30	1.10	.50	1.12	1.25	1.20	1.30	

Mean daily gage height, in feet, of Republican River at Benkelman, 1894–1906—Cont'd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906.												
26				1.10	1.10				1.10		1.10	
27				1.90	1.10		1.35	0 95	1.05	1.20	1.20	
28				1.60	1.00		1.05	.85	1.00	1.15		
29				1.60	1.05	0 85		.85	1.00	1.15	1.10	
30					1.10	.80			1.00	1.15	1.10	
31					1.10		.90	.90		1.20		

Mean daily discharge, in second-feet, of Republican River at Benkelman, 1895–1906.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Day.	Mar.	Apr.	May.	June.	July.	Aug.
1895.							1895.						
1		54	42	383	348	102	17	162	57		94	56	27
2	77	54	33	310	169	89	18	152	60		122	51	15
3	65	52	29	170	102	89	19	152	48		86	48	12
4	29	57	29	142	102	78	20	110	51		55	56	30
5	35	65	29	147	78	73	21	91	54		55	83	1
6	42	82	22	135	78	66	22	73	49	2	55	156	15
7	54	91	17	130	56	64	23	72	42	2	38	127	64
8	51	82	17	118	56	58	24	75	34	4	38	115	15
9	57	82	13	123	61	21	25	73	34	2	40	115	12
10	57	73	8	135	89	16	26	73	33	2	38	89	10
11	57	65	5	830	102	15	27	72	95		34	86	
12	49	57	4	550	102	16	28	65	82		34	78	
13	49	54	2	374	102	15	29	62	73		38	73	
14	111	52	2	122	303	58	30	57	49	223	38	66	1
15	130	51		103	96	44	31	49		281		73	
16	152	54		103	91	29							

Day.	May	June.	July.	Aug.	Sept.	Oct.	Nov.	Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1903.								1903.							
1		57	40	61	19	47	54	17		61	47	40	40	47	61
2		61	36	47	19	50	54	18		61	47	40	43	47	57
3		61	29	40	19	47	57	19		54	47	36	43	47	57
4		61	43	40	19	47	54	20	57	54	54	36	43	50	64
5		61	47	33	23	50	54	21	57	54	47	33	47	50	
6		61	33	26	36	47	54	22	47	47	40	29	47	50	
7		81	29	26	36	47	57	23	47	47	40	29	47	50	
8		78	26	26	33	47	54	24	50	47	36	29	47	50	
9		71	26	26	33	50	54	25	47	47	26	26	47	47	
10		68	29	33	40	50	54	26	64	50	26	29	43	47	
11		71	112	26	40	50	50	27	71	47	23	36	47	50	
12		68	61	29	40	50	54	28	68	47	19	29	47	50	
13		68	40	29	40	47	54	29	64	47	19	29	47	50	
14		68	33	26	40	50	57	30	61	43	19	26	47	54	
15		64	54	26	40	47	54	31	64		23	26		54	
16		64	64	26	43	43	57								

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.											
1		87	111	87	55	46	165	10	55	65	65
2		76	111	99	76	55	111	0	55	65	87
3		111	111	55	111	46	30	10	87	65	65
4		65	111	87	211	65	65	0	195	65	
5		65	111	76	65	46	46	0	30	65	
6		99	111	76	76	38	46	5	30	65	
7		65	124	76	55	211	46	10	30	65	136
8		76	105	38	55	143	46	17	30	55	
9		111	87	38	76	76	38	17	30	55	
10		99	76	46	151	65	30	17	46	55	
11		87	87	38	99	46	17	17	46	55	
12		87	46	30	99	30	46	13	30	55	
13		99	46	23	151	30	10	13	38	65	
14		87	38	23	99	17	10	13	30	55	
15		111	38	46	99	30	10	10	38	76	

Mean daily discharge, in second-feet, of Republican River at Benkelman, 1895–1906—Con.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.											
16		87	38	46	87	17	10	14	30	55	
17		87	30	46	137	13	10	17	38	65	
18		46	30	46	137	10	10	13	101	55	
19		76	30	46	65	17	17	13	165	55	
20		87	30	46	46	65	17	13	87	65	
21		99	30	55	35	30	17	13	87	55	
22		87	38	65	76	30	17	13	65	65	
23		99	30	87	87	17	13	13	65	87	
24		99	47	46	227	46	10	13	55	65	
25		99	65	46	65	17	10	17	65	55	
26		65	65	46	55	10	10	17	46	65	
27		99	46	55	55	10	10	17	65	76	
28	76	87	38	65	46	10	10	31	65	80	
29	76	99	30	46	55	10	10	46	65	83	
30		111	87	46	55	5	10	46	65	87	
31		111		46		5	10		65		
1905.											
1			242	145	117	74	98	8	72		
2			262	130	95	102	72	8	72		
3			205	138	68	65	98	8	72		
4			154	138	58	42	85	22	72		
5			175	138	68	27	62	30	72		
6			160	138	58	40	98	45	72		
7			160	138	42	40	72	55	72		
8			175	160	27	57	60	45	60		
9			175	160	42	77	60	105	50		
10			192	160	74	77	60	105	72		
11			175	127	102	77	83	78	72		
12			167	127	87	50	110	55	72		
13			167	120	90	50	83	78	72		
14			167	103	55	40	60	77	72		
15			167	103	55	35	57	53	103		
16			167	103	65	35	57	77	72		
17			150	103	118	54	47	53	72		
18			150	108	90	47	47	77	72		
19		237	142	138	65	32	37	103	72		
20		217	157	108	55	58	37	103	72		
21		165	175	122	55	72	37	77	85		
22		105	157	108	103	86	35	72	103		
23		130	270	97	55	72	10	72	85		
24		120	328	142	55	72	10	50	85		
25		115	230	142	42	67	10	72	85		
26		148	178	127	55	67	15	72	85		
27		165	145	127	55	67	35	72	103		
28		165	162	117	42	136	10	72	112		
29		122	178	182	42	136	10	50	142		
30		93	162	148	42	310	6	50	176		
31		170		117		125	3		195		
1906.											
1			115	130	78	10	24	17	57	122	
2			102	102	67	17	24	24	57	150	
3			102	102	67	17	24	24	57	150	
4			102	88	67	13	24	42	57	150	
5			102	130	56	10	42	32	47	150	
6			88	130	42	10	62	24	47	150	
7			102	102	36	32	42	24	67	135	
8			102	145	24	51	42	17	67	135	
9			102	145	17	51	42	17	67	135	
10			102	115	17	51	42	17	67	135	
11			102	115	14	42	42	20	78	135	
12			102	100	14	42	42	24	78	135	
13			102	100	14	26	42	24	74	142	
14			115	100	20	10	24	24	70	150	
15			115	113	263	10	24	24	67	150	
16			115	113	160	10	24	24	93	150	
17			122	67	57	10	24	32	105	167	
18			130	67	47	4	10	42	67	147	
19			130	74	47	2	10	42	78	163	
20			130	74	17	2	10	62	78	163	

Mean daily discharge, in second-feet, of Republican River at Benkelman, 1895–1906—Con.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906.											
21			130	80	10	1	10	62	100	163	
22			130	75	26	0	2	62	100	163	
23			115	185	42	0	32	70	100	180	
24			130	295	42	2	62	70	100	180	
25			115	145	62	0	66	108	122	180	
26			102	87	40	64	48	70	122	117	
27			398	82	40	128	32	57	122	147	
28			275	59	40	51	17	47	105	132	
29			275	70	17	38	17	47	105	117	
30			200	82	10	37	20	47	105	117	
31				82		24	24		122		

Estimated monthly discharge of Republican River at Benkelman.

[Drainage area, 3,960 square miles.]

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
March.								
1895	162	29	78	4,640	0.020	0.02	13	0.15
1904	111	46	89	5,480	.022	.02	25	.08
1905	237	93	151	3,890	.038	.04	1.0	3.82
April.								
1895	95	33	59	3,520	.015	.02	.7	2.78
1904	124	30	65	3,870	.016	.02	.8	2.46
1905	328	142	183	10,900	.046	.05	1.3	3.76
1906	398	88	135	8,030	.034	.04	.9	4.15
May.								
1895	281	0	25	1,540	.006	.01	.4	2.58
1903 [a]	71	47	58	1,380				2.64
1904	99	23	54	3,310	.014	.02	.8	2.02
1905	182	97	129	7,930	.032	.04	1.2	3.20
1906	295	59	108	6,640	.027	.03	1.2	2.51
June.								
1895	830	34	155	9,220	.039	.04	1.1	3.62
1903	81	43	59	3,510	.015	.02	1.2	1.69
1904	227	46	91	5,430	.023	.03	.5	6.25
1905	118	27	66	3,920	.017	.02	.8	2.65
1906	263	10	48.4	2,880	.012	.01	.5	2.06
July.								
1895	656	41	120	7,380	.030	.04	.9	4.62
1903	112	19	39	2,400	.010	.01	.2	5.16
1904	211	5	40	2,520	.010	.01	.5	1.64
1905	310	27	73.8	4,540	.019	.02	.5	3.81
1906	128	0	24.7	1,520	.006	.01	.4	2.77
August.								
1895	102	0	34	2,090	.008	.01	1	1.02
1903	61	26	32	1,970	.008	.01	.7	1.48
1904	165	10	29	1,780	.007	.01	.8	1.21
1905	110	3	50.5	3,110	.013	.01	1.2	.84
1906	62	2	30.6	1,880	.007	.01	.5	2.14
September.								
1903	47	19	39	2,320	.010	.01	1.3	.78
1904	46	0	15	892	.004	.004	.1	2.67
1905	105	8	61.5	3,660	.015	.02	1.2	1.64
1906	108	17	39.9	2,370	.011	.01	.7	1.38
October.								
1903	54	43	49	3,010	.012	.01	3	.33
1904	195	30	61	3,750	.015	.02	1.5	1.30
1905	195	50	87	5,340	.022	.02	1.2	1.67
1906	122	47	83.3	5,120	.021	.02	1.1	1.81
November.								
1903 [b]	64	50	56	2,220				.25
1904	87	55	64	3,810	.016	.02	67	.03
1906	180	117	147	8,750	.037	.04	4.4	.90

[a] May 20 to 31.

[b] November 1 to 20.

REPUBLICAN RIVER AT BOSTWICK.

The station established June 6, 1904, at Bostwick replaced an old station at Superior established in 1895. It is located at a highway bridge 1 mile south of Bostwick, in sec. 23, T. 1 N., R. 8 W., and is shown on the Superior topographic atlas sheet.

At the gaging station the channel is straight and the bed is composed of shifting sand. The left bank is high, but the right bank is low and is subject to overflow at high stages. The channel is somewhat obstructed by ice breakers and piers. The water is never sluggish, even at low stages.

Measurements are made from a steel highway bridge.

The gage is of the standard weight and chain type, the length of the chain from the index to the end of the weight being 20.52 feet. It is referred to bench marks as follows: (1) The downstream opening in a cast-iron bearing shoe at the left end of the downstream truss; elevation, 15.75 feet above the zero of the gage. (2) The northeast cardinal point of the steel rim of the cover plate at the right pier of the truss described above; elevation, 15.89 feet above the zero of the gage.

As there are no tributaries or important diversions between the two points, the tables of discharge for Bostwick and Superior are presented as from one station.

REPUBLICAN RIVER AT SUPERIOR.

The station established June 20, 1896, at Superior was abandoned at the close of the open season of 1903, because, owing to the complicated conditions affecting the discharge of the river, the results were unsatisfactory. It was replaced by the station at Bostwick, 10 miles upstream. The location of the station—at the highway bridge 1 mile west of Superior—is shown on the Superior topographic atlas sheet.

The gage, which was of the inclined type, was installed on the left bank of the river 25 feet above the bridge. It was referred to a standard United States Geological Survey bench mark, 83 feet north of the upstream left pier; elevation, 4.88 feet above the zero of the gage. This bench mark was later destroyed as the result of repairs to the bridge.

The conditions at this station were complicated by a mill dam and race just below the gaging station, and the results of an attempt to utilize the diversion dam as a measuring weir were further complicated by the intermittent use of flash boards and by leakage through the dam. The gage above referred to was used during 1896 and 1897. On April 19, 1898, two other gages were installed, one a few feet above the dam, with its zero at the mean elevation of the crest, and the other in the mill race 50 yards below the head. The gage heights

in the mill race were found to be no index to the discharge, because the flow was entirely controlled by the mill one-half mile below. The observer was therefore instructed to supplement the gage readings by noting the time required for a float to pass over a 50-foot range in the midstream of the mill race. Measurements of discharge were made as before at the highway bridge above both dam and mill race. The discharge of the mill race was also measured in order that the net amount flowing over the dam could be determined as a more stable relation between gage heights, and the amount of water flowing at the dam was thereby obtained. These two gages were referred to two bench marks. The zero of the gage at the dam is 4.92 feet and the zero of the gage in the race is 6.92 feet below the Survey standard bench mark described above. The zero of the gage at the dam is also 9.07 feet below the top of an oak piling in line with the crest of the dam and east of the left retaining wall.

The procedure above outlined was continued during 1898. In 1899 and subsequent years, however, the gage in the mill race was not read, because when the mill was not running the channel of the race silted up so that the cross section area was greatly reduced. The observer was instructed to note, however, the depth of water in the midstream of the race. The ratio of such "center depths" to the "time in seconds" simultaneously observed for a float to pass over a 50-foot range in midstream was found to bear a close relation to the discharge in the mill race.

Discharge measurements of Republican River at Superior, 1896–1903.

Date.	Hydrographer.	River.		Date.	Hydrographer.	River.	
		Gage height.	Discharge.			Gage height.	Discharge.
1896.		*Feet.*	*Sec.-ft.*	1897.		*Feet.*	*Sec.-ft.*
June 20	O. V. P. Stout	0.92	700	April 24	Adna Dobson	0.99	887
July 17	E. T. Youngfeldt	.78	585	May 18	do	.45	337
August 24	do	.89	684	June 12	O. V. P. Stout	.72	716
September 21	do	.42	228	July 8	do	.87	766
October 25	R. A. Trail	.45	72	July 18	do	.32	222
December 23	E. T. Youngfeldt	.73	515	August 6	do	.49	372
				August 22	do	.05	195
1897.				September 25	Adna Dobson	.04	81
April 12	Adna Dobson	1.12	1,257	October 24	do	.02	184

Date.	Hydrographer.	River.		Mill race.	
		Gage height.	Discharge.	Gage height.	Discharge.
1898.		*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
April 20	Glenn E. Smith	0.79	626	2.79	87
May 10	do	1.16	1,337	3.39	65
May 27	do	1.05	1,030	3.12	50
June 17	do	1.40	1,573	3.60	52
June 27	O. V. P. Stout	.89	679	2.91	52
July 19	Glenn E. Smith	.60	416	2.50	85
August 6	do	.30	119	2.29	56
August 28	Adna Dobson	.15	76	2.35	11
September 13	Glenn E. Smith [a]	1.40	252	3.40	60
October 9	Adna Dobson [a]	1.18	143	3.40	8
November 5	Glenn E. Smith	.50	380	2.50	86

[a] Water surface raised by 12-inch flush boards placed on crest of dam.

Discharge measurements of Republican River at Superior, 1896–1903—Continued.

Date.	Hydrographer.	River.		Mill race.		
		Gage height.	Discharge.	Center depths.[a]	Time.[b]	Discharge.
1899.		*Feet.*	*Sec.-ft.*	*Feet.*	*Seconds.*	*Sec.-ft.*
January 24	Glenn E. Smith	Ice.	463			
February 14	do	Ice.	131			
April 10	do	0.98	728	2.98	52	49
May 1	do	.75	382	3.00	Dead.	0
May 13	do	.61	442	3.10	46	47
June 2	do	.51	291	2.60	44	55
June 16	do	.63	439	3.50	55	53
June 26	do	.42	204	3.40	45	59
July 6	do	.90	732	2.80	50	56
July 26	do	.23	135			
August 11	do	.40	215	2.70	40	56
September 6	do		0	2.60	45	50
September 29	do		0	1.20	25	25
October 17	do		0	1.50	35	50
1900.						
April 15	Adna Dobson	.91	989			
April 26	do	1.06	1,059	1.14	32	79
May 19	O. V. P. Stout	.63	457	2.60		113
June 1	Adna Dobson	.54	374	3.20	50	93
June 21	do	.43	312	3.10	70	58
August 16	O. V. P. Stout[c]	1.73	433			
September 30	Adna Dobson[c]	1.21	67			
October 23	do.[c]	1.31	118			
1901.						
April 14	O. V. P. Stout	1.57	1,189	3.7	96	21
May 29	Adna Dobson	.41	250	2.4	18	139
July 27	O. V. P. Stout	(*d*)	45			
September 10	do	2.28	2,237	5.0	245	17
November 15	Frank Dobson	.90	370	2.9	36	72
1902.						
March 16	do	.75	625	3.0	110	22
April 5	J. C. Stevens	.70	638	2.6	40	54
May 24	Frank Dobson	1.30	1,499	1.8		35
July 8	J. C. Stevens	6.00	12,494	(*e*)	(*e*)	(*e*)
July 30	do	1.25	1,562	1.9	18	119
August 12	do	.72	553	2.3	35	54
September 19	do	.39	154	2.4	720	3
1903.						
April 11	do	.80	950	3.7	33	87
May 19	do	1.35	2,198	3.4	14	244
June 4	do	1.76	2,896	3.6	30	85
June 23	do	1.05	1,008		40	78
July 14	do	3.20	7,662			
September 12	do	.42	364	2.8		158

[a] Depth of water in midstream at bridge.
[b] Time in seconds required for a float to pass over a 50-foot range in midstream.
[c] Water surface raised by 12-inch flash boards placed on crest of dam.
[d] No water at the gage rod.
[e] Mill race overgorged with flood waters running backward into the river.

Discharge measurements of Republican River at Bostwick, 1904–1906.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
1904.		*Feet.*	*Sec.-ft.*	1905.		*Feet.*	*Sec.-ft.*
June 5	J. C. Stevens	2.10	884	July 26	H. C. Gardner	5.45	5,915
June 6	do	2.64	1,289	August 10	do	3.55	3,082
June 29	do	3.50	2,379	September 30	F. S. Dobson	1.32	648
July 8	R. D. Hubbard	3.05	1,799	1906.			
August 16	do	1.50	397	April 7	do	2.00	590
December 8	J. A. Green	1.70	520	May 19	do	1.66	832
1905.				June 13	Arthur Dobson	1.05	391
March 22	H. C. Gardner	2.45	1,181	July 19	do	.75	276
April 29	do	3.00	2,009	August 30	do	.84	267
June 7	do	2.55	1,045	October 13	do	.68	187
July 6	do	8.30	14,870				

Mean daily gage height, in feet, of Republican River at Superior, 1896–1903.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1896.												
1							0.89	1.09	0.44	0.35	0.51	
2							2.90	1.07	.41	.32	.44	
3							3.12	1.04	.48	.35	.56	0.70
4								.67	.42	.36	.52	
5							2.33	.67	.34	.38	.50	.70
6							1.88	.67	.33	.36	.52	
7							1.65	1.35	.32	.33	.51	.64
8							1.76	.93	.31	.30	.61	.70
9							1.74	1.69	.32	.32	.60	
10							1.52	.67	.42	.30	.64	
11							1.38	.61	.50	.35	.59	
12							1.27	.52	.47	.30	.63	.71
13							1.10	.47	.45	.32	.64	
14							1.00	.42	.62	.30	.68	.70
15							.92	.41	.45	.30	.73	
16							.86	.36	.45	.32	.74	
17							.76	1.43	.43	.32	.72	
18							.78	1.47	.60	.31	.68	
19							.76	1.18	.46	.30	.58	
20						0.92	.74	.82	.47	.32	.50	.85
21						.81	.79	.79	.42	.35	.54	.73
22						.72	.65	.98	.46	.42	.57	.73
23						.76	.69	.90	.48	.36	.61	.73
24						.64	.65	.84	.44	.34	.55	.73
25						.65	.64	.82	.35	.36	1.10	.73
26						1.25	.62	.73		.34	1.25	.73
27						.85	.57	.67	.42	.36	.65	.73
28						.88	.56	.63	.40	.35	.66	.73
29						.85	.59	.55	.45	.61		.73
30						.82	.63	.51	.44	.57	.70	.74
31							1.15	.46		.55		
1897.												
1		1.01			0.87	.28	1.48	.08	.12	− .12		
2	0.75	1.01	0.84	0.97	.77	.27	.75	.12	.06	− .34		
3	.80	1.01			.69	.32	1.65	.08	.01	.00		
4	.80	1.01		1.00	.67	.32	1.39	.07	−.06	− .35		
5	.80	1.01		1.67	.64	.27	1.35	.12	.04	− .30		
6	.80	1.01	.70	1.50	.66	.36	2.15	.48	.03	− .58		
7	.80	1.01	.70	1.05	.63	.54	1.64	.20	.01	− .30		
8	.80	1.01		1.18	.60	.40	1.80	.57	−.20	− .52		
9	.80	1.01		1.12	.77	.34	1.48	.56	−.25	− .71		
10	.80	1.01	.64	1.08	.80	.31	1.06	.45	−.16	− .50		
11	.80	1.01		1.09	.66	.92	.94	.45	−.02	− .35		
12	.80	1.01		1.12	.62	.74	.70	.56	.20	− .30		
13	.80	1.01		1.14	.60	.54	.51	.54	.60	− .53		
14	.80			1.07	.54	.71	.39	.55	.00	− .58		
15	.80	1.01	.71	1.09	.52	.48	.34	.10	.01	− .90		
16	.80			1.62	.50	.76	.28	.14	.36	+ .04		
17			.55	1.31	.48	.79	.28	.14	.26	1.22		
18				1.14	.45	.74	.32	.18	.26	1.30		
19		1.00		1.08	.42	.66	.25	.21	.15	1.25		
20	.90		.61	1.05	.38	.68	.34	.31	.10	1.19		
21		.60		1.03	.35	.58	.30	.24	.05	1.11		
22			.86	1.02	.37	.47	.22	.30	.04	1.10		
23	1.01		.65	.92	1.10	.43	.66	.27	−.05	1.11		
24	1.01			1.00	.63	.48	.69	.57	.01	− .05		
25	1.01	1.22		.98	.61	.33	.15	.50	.02	−1.06		
26	1.01			.88	.57	2.42	.23	.39	−.35	1.08		
27	1.01		.64	.82	.63	4.38	.16	.31	−.12	2.45		
28	1.01			1.32	.42	1.87	.84	.26	−.09	2.32		
29	1.01			1.20	.40	1.78	.30	.23	−.06	1.53		
30	1.01			.98	.32	1.72	.17	.14	−.05	1.45		
31	1.01		.81		.27		.14	.11				
1898.												
1					.69	1.21	.70	.30	.09	1.27	.47	
2					1.23	1.06	.73	.34	(a)	1.34	.49	
3					.85	1.04	.68	.31	(a)	1.21	.50	
4					.86	1.02	.51	.30	2.00	1.21	.54	
5					.90	1.04	.61	.30	(a)	1.22	.50	

[a] Water below gage.

Mean daily gage height, in feet, of Republican River at Superior, 1896–1903—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1898.												
6					1.00	1.19	0.61	0.30	0.59	1.21	0.59	
7					1.04	1.03	.60	.24	.53	1.24	.53	
8					1.14	1.44	.60	.34	.52	1.28	.52	
9					1.02	1.26	.72	.26	.53	1.31	.53	
10					1.16	1.27	1.24	.24	.09	1.39	.51	
11					1.03	1.70	1.04	.21	[a]1.17	1.40	.52	
12					.99	1.41	.72	.17	1.35	[b]1.45	.59	
13					1.14	1.34	.74	.18	1.42	.43	.64	
14					1.22	1.38	.99	.34	1.35	.41	.59	
15					.93	1.38	.87	.20	1.34	.40	.60	
16					.99	1.36	.74	.21	1.24	.49	.60	
17					.96	1.40	.73	.21	1.25	.53	.65	
18					.98	1.26	.67	.17	1.35	.43	.63	
19					.95	1.47	.61	.18	1.30	.45	.63	
20				0.77	1.04	1.29	.55	.05	1.30	.43	.72	
21				.77	1.33	1.20	.51	.16	1.65	.42		
22				1.02	1.42	1.11	.60	(a)	1.59	.44		
23				1.63	1.24	1.18	.50	(a)	1.55	.54		
24				1.00	1.00	1.07	.50	.55	1.40	.44		
25				.81	.98	.99	.40	.40	1.47	.43		
26				.76	1.07	.88	.50	.31	1.35	.47		
27				.74	.99	.89	.41	.29	1.32	.39		
28				.74	1.05	.84	.40	.35	1.32	.49		
29				.68	1.50	.80	.40	.28	1.31	.47		
30				.71	1.39	.74	.32	(a)	1.29	.59		
31					1.13		.41	(a)		.49		
1899.												
1				.97	.74	.45	1.05	.91	.12	(a)		
2				1.00	.70	.51	.90	.95	.09	(a)		
3				.95	.73	.60	.80	.82	.20	(a)		
4				.94	1.18	.60	.80	.68	(a)	(a)		
5				1.00	.68	.47	.79	.60	(a)	(a)		
6				.98	.64	.45	.90	.45	(a)	(a)		
7				1.04	.50	.47	.93	.52	(a)	(a)		
8				.97	.61	.45	.89	.42	(a)	(a)		
9				1.00	.68	.40	.63	.41	(a)	(a)		
10				.97	.63	.40	.51	.41	(a)	(a)		
11				.94	.63	.41	.45	.40	(a)	(a)		
12				.89	.60	.35	.42	.41	(a)	(a)		
13				.90	.61	.33	.52	.50	(a)	(a)		
14				.90	.67	.70	.47	.60	(a)	(a)		
15				.88	.63	.53	.42	.44	(a)	(a)		
16				.74	.69	.63	.45	.39	(a)	(a)		
17				.83	.65	.42	.45	.62	(a)	(a)		
18				.83	.64	.41	.46	.52	(a)	(a)		
19			1.13	.82	.65	.12	.39	.42	(a)	(a)		
20			.94	.77	.93	.35	.40	.41	(a)	(a)		
21			.89	.82	1.50	.35	.49	.27	1.25	(a)		
22			.99	.73	1.02	.32	.42	.35	(a)	(a)		
23			.99	.63	.80	.60	.35	.31	(a)	(a)		
24			.96	.75	.74	.63	.20	.20	(a)	(a)		
25			.92	.70	.70	.39	.26	.30	(a)	(a)		
26			.94	.73	.80	.42	.26	.45	(a)	(a)		
27			.93	.75	.73	2.60	.25	.72	(a)	(a)		
28			.95	.75	.66	2.05	.26	.33	(a)	(a)		
29			.92	.79	.65	1.31	1.22	.21	(a)	(a)		
30			.91	.70	.63	1.22	.69	.33	(a)	(a)		
31			.96		.54		.45	.20		(a)		
1900.												
1				.74	.94	.73	.41	1.14	(a)	.94	.83	
2				.73	.92	.52	.39	1.35	(a)	.82	.98	
3				.65	.90	.52	.30	− .25	(a)	.65	1.09	
4				.65	.89	.49	.18	− .42	(a)	.99	1.23	
5				.65	.84	.49	.21	1.29	(a)	.15	1.10	
6				.64	.97	.48	.20	1.22	(a)	.15	1.12	
7				.64	1.13	.43	.09	− .67	(a)	.01	1.15	
8				.67	2.11	.39	.21	.01	(a)	.39	1.11	
9				.62	1.61	.35	.09	− .08	(a)	.44	1.31	
10				.64	1.25	.25	.39	−1.50	(a)	(a)	1.35	

[a] Water below gage. [b] Flashboards 1 foot high on dam from September 11 to October 12, 1898.

Mean daily gage height, in feet, of Republican River at Superior, 1896–1903—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1900.												
11				0.64	1.10	0.53	0.24	(a)	1.72	0.03	1.29	
12				.66	1.02	.73	.19	(a)	2.62		1.31	
13				.80	.92	.79	.07	(a)	1.67	.22	1.30	
14				.75	.90	.58	−.50	(a)	1.40	(a)	1.21	
15				.91	.82	.51	−.58	0.21	1.30	.41	1.24	
16				1.00	.77	.65	.51	2.25	1.32	.25	1.29	
17				1.10	.74	.41	.73	1.52	1.16	(a)	1.20	
18				1.04	.66	.42	.90	1.40	1.22	.13	1.32	
19				.98	.63	.42	1.05	1.42	1.19	.28	1.22	
20				.98	.59	.41	1.23	1.24	1.17	.07	1.25	
21				1.20	.62	.43	1.20	1.23	1.13	1.37		
22				1.09	.62	.52	1.22	1.20	1.05	1.28		
23				1.00	.59	.57	1.14	1.20	1.21	1.31	1.20	
24				1.41	.63	.41	1.21	1.15	1.02	1.26	1.32	
25				1.01	.70	.53	1.14	1.03	.82	1.22		
26				1.06	.63	.53	1.18	.91	(a)	1.30		
27				1.11	.59	.54	1.09	.90	.23	1.15		
28				1.17	.49	.50	.72	.99	.32	1.25		
29				1.13	.49	.43	1.63	.10	.39	1.12		
30				1.00	.58	.38	1.46	(a)	.83	1.06		
31					.49		1.30	(a)		.87		
1901.												
1				1.21	1.21	.47	.38	(a)	(a)	1.15	1.10	
2				1.21	1.12	.53	.51	(a)	(a)	1.83	1.50	
3				1.24	1.11	.52	.43	(a)	(a)	1.50	.91	
4				1.32	1.12	.42	.45	(a)	(a)	1.00	.90	
5				1.30	.98	.40	.32	(a)	(a)	1.13	1.00	
6				1.47	1.12	.40	.32	(a)	2.12	1.00	.84	
7				1.46	1.09	.42	.35	(a)	1.91	1.00	.82	
8				1.43	1.05	.47	.31	(a)	2.02	1.08	1.00	
9				1.47	.85	.50	(a)	(a)	2.41	1.10	.85	
10				1.48	.81	.45	(a)	(a)	2.25	.93	.80	
11				1.50	.91	.40	(a)	1.42	3.10	.93	.93	
12				1.52	.99	.39	(a)	1.38	3.45	.93	.90	
13				1.52	.85	.39	(a)	.30	2.75	.95	.98	
14				1.57	.90	.49	(a)	.30	2.10	.90	.98	
15				1.73	.88	.82	(a)	(a)	2.58	.92	.90	
16				1.79	.90	.25	(a)	(a)	2.19	.90	.88	
17				1.71	.72	.36	(a)	(a)	2.01	.93	.80	
18				1.65	.75	.50	(a)	(a)	1.08	.90	.97	
19				1.68	1.01	.69	(a)	(a)	1.07	.92	.93	
20				1.69	.70	.75	(a)	(a)	1.07	.80	.94	
21				1.61	.82	1.09	(a)	(a)	1.05	.88	1.00	
22				1.51	.61	1.00	(a)	(a)	1.05	.90	.93	
23				1.42	.82	1.05	(a)	(a)	1.04	.78	1.00	
24				1.35	.65	1.12	(a)	(a)	1.03	.88	.80	
25				1.31	.65	.97	(a)	(a)	1.02	.90	1.00	
26				1.28	.69	.88	(a)	(a)	1.02	.78	1.00	
27				1.31	.62	.78	(a)	(a)	1.02	.76	.98	
28				1.30	.45	.73	(a)	(a)	1.01	.80	1.03	
29				1.27	.41	.69	(a)	(a)	1.40	.90	.98	
30				1.25	.59	.65	(a)	(a)	1.20	1.10	.95	
31					.59		(a)	(a)		.98		
1902.												
1				.80	.56	1.10	1.98	1.42	.70	1.00	.60	
2				.80	.50	1.00	2.32	1.20	.68	.98	.60	
3				.71	.70	1.05	2.05	1.05	.65	1.05	.59	
4				.73	.46	1.32	1.30	1.18	.61	1.19	.55	
5				.70	.49	.95	2.40	.95	.60	1.35	.56	
6				.70	.53	1.95	(b)	.92	.58	1.00	.63	
7				.62	.90	1.90	(b)	.90	.52	.98	.60	
8				.56	1.02	1.92	(b)	.82	.53	.90	.61	
9			0.90	.55	1.15	1.48	(b)	.80	.45	.89	.62	
10			.85	.58	.85	1.30	3.50	.70	.42	.82	.70	
11			.80	.68	.75	1.42	2.55	.81	.48	.88	.71	
12			.80	.78	.69	1.00	1.88	.70	.40	1.05	.73	
13			.80	.68	.86	.95	1.92	.62	.32	1.45	.74	
14			.83	.60	.80	.88	1.72	.80	.31	1.00	.78	
15			.75	.60	.78	1.05	1.42	.78	.40	.85	.71	

[a] Water below gage.

[b] Flood; water over top of gage.

Mean daily gage height, in feet, of Republican River at Superior, 1896–1903—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
16			0.75	0.62	0.70	0.82	1.30	0.65	0.41	0.82	0.78	.....
17			.70	.68	.70	.70	1.15	.60	.32	.99	.74	.....
18			.85	.65	.75	.85	1.68	.55	.48	.90	.79	.....
19			.80	.62	1.85	1.38	1.80	.52	.34	.91	.75	.....
20			.64	.70	1.69	1.20	1.10	.51	.35	.83	.74	.....
21			.60	.65	1.53	1.20	1.05	.40	.40	.78	.71	.....
22			.75	.63	1.42	1.08	1.00	.52	1.85	.70	.71	.....
23			.78	.67	1.20	.95	.92	.68	3.60	.71	.67	.....
24			.75	.65	1.30	.90	1.02	.50	2.32	.72	.80	.....
25			.68	.62	1.56	.82	1.08	.50	1.86	.70	.80	.....
26			.80	.58	1.95	.76	(a)	.50	1.78	.73	.70	.....
27			.81	.60	1.95	.68	3.25	.60	1.35	.75	.90	.....
28			.97	.56	1.65	.65	3.00	.58	1.10	.75	.70	.....
29			.52	.56	1.75	.78	1.60	.59	1.05	.72	.80	.....
30			.83	.52	1.25	1.10	1.20	.67	1.02	.71	.....	.....
31			.81	.....	1.20	.....	1.70	.62	.....	.72	.....	.....
1903.												
1				1.18	.80	2.60	1.05	2.10	.90	.39	.70	.....
2				1.12	.86	2.10	.96	2.08	.75	.38	.79	....
3				1.11	.96	1.89	.92	1.70	.61	.38	.62	.....
4				1.11	.80	1.76	.88	1.88	.65	.19	.69	....
5				1.00	.95	1.58	.80	1.28	.62	.40	.60	.....
6				1.03	.99	1.45	.79	1.10	.56	.42	.60	.....
7				1.01	1.09	1.33	1.55	1.03	.52	.40	.62	.....
8				1.00	2.02	1.44	1.30	.95	.50	.34	.70	.....
9				.97	2.08	1.41	1.13	.85	.48	.40	.61	.....
10				.95	2.59	1.20	.99	.83	.49	.35	.57	.....
11				.80	3.20	1.19	1.80	.78	.46	.45	.64	.....
12				.86	2.75	1.21	2.41	.89	.42	.46	.62	.....
13				.81	2.60	1.13	2.76	1.12	.40	.50	.12	.....
14			3.10	.80	2.32	1.03	3.18	1.84	.39	.51	.02	.....
15			2.81	.90	2.08	1.07	2.90	1.20	.38	.50	.02	.....
16			2.21	.88	1.99	1.04	2.78	1.10	.40	.47	.50	.....
17			2.08	.92	1.68	1.00	1.76	.92	.40	.49	.02	.....
18			1.98	.90	1.42	.99	1.42	.89	.40	.55	.42	.....
19			1.95	.75	1.41	.96	2.10	1.02	.38	.49	.40	.....
20			1.88	.83	1.33	.91	1.75	1.02	.43	.50	.40	.....
21			1.60	.85	1.20	.96	1.47	1.09	.41	.50	.46	.....
22			1.59	.87	1.54	.94	1.30	1.05	.36	.51	.60	.....
23			1.42	.80	1.41	1.09	1.11	.81	.40	.49	.72	.....
24			1.44	.78	1.30	1.08	1.00	.82	.42	.50	.62	.....
25			1.35	.83	3.48	1.16	.91	.75	.36	.53	.60	.....
26			1.30	.81	2.80	1.29	.88	.73	.31	.50	.63	.....
27			1.29	.72	2.32	1.76	.87	.78	.47	.50	.70	.....
28			1.28	.76	1.96	1.58	.80	1.42	.37	.51	.80	.....
29			1.18	.88	3.88	1.41	.80	1.90	.38	.50	.79	.....
30			1.20	.92	3.76	1.19	.78	1.46	.40	.53	.75	.....
31			1.21	.....	2.88	.....	.76	1.20	.....	.52	.....	.....

a Flood; water over top of gage.

Mean daily gage height, in feet, of Republican River at Bostwick, 1904–1906.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.										
1					2.90	1.45	1.40	1.40	1.60	1.70
2					2.70	1.40	1.25	1.35	1.70	.....
3					2.65	1.40	1.20	1.30	1.75	.....
4					3.70	1.45	1.30	1.35	1.70	.....
5					6.10	1.50	1.40	1.40	1.70	.....
6				2.40	6.25	1.75	1.25	1.35	1.70	.....
7				2.20	3.70	1.70	1.30	1.35	1.65	.....
8				1.50	3.05	2.30	1.25	1.30	1.65	.....
9				2.10	3.07	2.20	1.15	1.35	1.70	.....
10				2.15	3.90	1.90	1.25	1.30	1.65	.....
11				2.00	3.40	1.70	1.25	1.35	1.65	.....
12				2.00	3.10	1.60	1.20	1.40	1.65	.....
13				1.95	3.25	1.00	1.20	1.35	1.65	.....
14				1.90	3.10	1.55	1.10	1.45	1.70	.....
15				3.10	2.75	1.50	1.05	1.40	1.65	.....

Mean daily gage height, in feet, of Republican River at Bostwick, 1904–1906—Continued.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.										
16				2.95	2.55	1.45	1.00	1.50	1.70	
17				2.40	2.30	1.45	1.00	1.45	1.70	
18				2.45	2.15	1.60	.95	1.40	1.70	
19				2.75	2.05	1.50	.90	1.45	1.65	
20				2.45	2.00	2.30	1.00	2.00	1.70	
21				2.75	2.00	1.85	.95	2.40	1.70	
22				2.50	1.95	1.70	1.00	2.30	1.70	
23				2.55	1.90	1.45	1.00	2.30	1.65	
24				3.68	1.85	1.45	.95	2.25	1.70	
25				4.10	1.80	1.40	1.00	2.15	1.70	
26				4.90	1.75	1.35	.95	2.10	1.70	
27				4.80	1.70	1.40	1.00	2.05	1.70	
28				3.85	1.65	1.35	1.15	1.95	1.70	
29				3.50	1.50	1.25	1.20	1.80	1.70	
30				3.10	1.50	1.40	1.30	1.70	1.70	
31					1.45	1.50		1.65		
1905.										
1		2.15	2.75	3.3	6.25	6.35	1.2	1.25		
2		2.15	2.55	3.3	8.7	6.45	1.2	1.15		
3		2.2	2.5	4.1	9.3	6.9	1.9	1.15		
4		2.15	2.45	3.7	10.4	7.3	1.9	1.15		
5		2.15	2.45	2.9	9.5	5.65	1.9	1.1		
6		2.15	2.35	2.65	7.65	5.3	1.9	1.1		
7		2.5	2.35	2.55	5.5	5.5	1.5	1.1		
8		2.4	2.35	2.35	4.75	4.65	1.3	1.1		
9		2.35	2.4	2.25	4.5	4.05	1.3	1.05		
10		2.25	2.45	2.35	4.6	3.8	1.9	1.0		
11		2.2	6.1	2.4	4.1	3.5	1.3	1.0		
12		2.2	2.7	2.5	3.6	3.05	1.3	1.0		
13		2.1	3.0	4.0	3.35	2.8	1.1	.95		
14		2.1	3.05	3.0	3.05	2.5	1.1	.95		
15		2.1	3.15	2.7	2.9	2.35	1.1	.95		
16		2.05	5.4	4.15	2.85	2.5	1.2	1.0		
17		2.1	4.1	4.55	2.8	2.65	1.1	.95		
18		2.05	3.15	5.5	2.7	2.85	1.3	1.0		
19		2.05	2.95	3.85	2.65	2.55	1.2	1.0		
20		2.0	2.7	3.5	4.1	2.15	1.4	1.05		
21		2.25	2.5	3.0	2.5	2.0	1.45	1.05		
22	2.45	2.05	2.45	2.85	2.4	1.85	1.4	1.05		
23	2.5	2.2	2.35	5.2	2.35	1.75	1.35	1.1		
24	2.45	2.45	2.45	5.75	2.25	1.7	1.45	1.1		
25	2.4	2.6	2.35	6.05	2.15	1.65	1.6	1.1		
26	2.4	2.95	2.25	5.85	5.7	1.65	1.55	1.1		
27	2.4	2.8	2.45	5.5	3.65	1.6	1.55	1.1		
28	2.3	3.1	2.25	4.15	3.5	1.5	1.5	1.1		
29	2.3	3.0	5.4	3.85	5.4	1.3	1.4	1.1		
30	2.25	2.9	3.9	4.15	4.65	1.3	1.35	1.1		
31	2.2		3.7		4.9	1.3		1.1		
1906.										
1			3.90	1.55		1.15	.80	.65	1.40	
2			4.95	1.50		1.10	.80	.65	1.40	
3			4.15	1.50		1.30	.75	.60	1.35	
4			3.85	1.50		1.65	.75	.60	1.35	
5			2.75	1.45		1.45	.70	.60	1.40	
6			2.55	1.45		1.35	.65	.70	1.40	
7			2.45	1.35		1.25	.60	.75	1.40	
8		2.15	2.65	1.30	1.15	1.15	.55	.80	1.40	
9		2.05	2.55	1.25	1.05	1.15	.65	.75	1.40	
10		1.95	2.45	1.25	1.00	2.10	.65	.70	1.40	
11		1.95	2.30	1.15	.90	2.45	.90	.65	1.40	
12		1.90	2.20	1.10	1.60	2.15	1.10	.65	1.40	
13		2.15	2.10	1.05	.95	1.65	.75	.70	1.40	
14		2.50	2.05	1.05	.90	1.50	.95	.70	1.40	
15		2.35	2.00	1.00	.90	1.40	1.15	.75	1.40	
16		2.15	1.95	1.00	.80	1.35	.85	.75	1.35	
17		2.05	1.90	1.00	.75	1.20	.85	.80	1.35	
18		2.00	1.85	.95	.70	1.15	.80	.80	1.40	
19		1.95	1.80	.90	.70	1.05	.80	.85	1.40	
20		1.95	1.65	.90	.80	1.00	.85	.90	1.35	

Mean daily gage height, in feet, of Republican River at Bostwick, 1904–1906—Continued.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906.										
21		1.95	1.60	0.85	1.25	0.90	0.80	1.00	1.35	
22		1.90	3.80	.85	2.95	.90	.80	1.35	1.30	
23		1.90	2.60	.80	2.95	.90	.80	1.45	1.30	
24		1.90	2.15	.80	2.60	1.10	.80	1.40	1.25	
25		1.85	1.80	.80	2.25	1.10	.75	1.35	1.30	
26		1.85	1.75	.85	2.15	.95	.75	1.45	1.35	
27		2.00	1.55	.95	2.10	.90	.75	1.60	1.35	
28		2.25	1.55	1.35	1.85	.85	.70	1.50	1.40	
29		2.35	1.65	1.55	1.40	.85	.70	1.50	1.40	
30		3.15	1.60	1.15	1.30	.85		1.45	1.40	
31			1.55		1.25	.80		1.45		

Daily center depth, in feet, of mill race on Republican River at Superior, 1898–1903.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1898.									
1			2.68	3.20	2.81	2.29	0.92	3.50	2.44
2			3.57	3.07	2.61	2.34	1.53	3.40	2.52
3			2.90	3.21	2.30	2.31	1.49	3.20	2.51
4			2.95	2.95	2.22	2.28	2.70	3.20	2.53
5			2.99	3.10	2.60	2.30		3.22	2.50
6			3.03	3.24	2.60	2.29		3.21	2.67
7			3.23	3.12	2.60	2.30		3.25	2.52
8			3.29	3.69	2.55	2.33	1.60	3.29	2.53
9			3.17	3.42	2.70	2.26		3.41	2.52
10			3.39	3.58	2.38	2.23	1.95	3.41	2.53
11			3.22	4.11	2.14	2.21	3.18	3.40	2.52
12			3.18	3.64	2.72	2.17	3.38	3.50	2.60
13			3.11	3.40	2.70	2.14	3.43	2.43	2.72
14			3.18	3.50	2.00	2.35	3.35	2.39	2.61
15			3.15	3.59	2.90	2.16	3.34	2.42	2.64
16			3.20	3.57	2.71	2.21	3.25	2.50	2.66
17			3.17	3.60	2.87	2.20	3.25	2.54	2.70
18			3.11	3.35	2.62	2.12	3.40	2.46	2.68
19			3.25	3.70	2.59	2.18	3.30	2.41	2.67
20		2.79	3.18	3.32	2.50	2.05	3.35	2.41	2.81
21		2.79	3.65	3.18	2.49	2.17	3.63	2.40	
22		3.37	3.89	3.00	2.45	1.70	4.69	2.40	
23		3.66	3.47	3.33	2.40	1.61	3.58	2.60	
24		3.17	3.08	3.12	2.50	2.55	3.50	2.41	
25		2.79	3.19	3.03	2.38	2.41	3.50	2.40	
26		2.69	3.12	2.55	2.51	2.29	3.39	2.43	
27		2.67	3.20	2.91	2.07	2.28	3.36	2.10	
28		2.65	3.12	2.87	2.38	2.35	3.32	2.50	
29		2.69	3.87	2.80	2.40	2.31	3.31	2.44	
30		2.70	3.60	2.77	2.31	1.11	3.30	2.60	
31			3.29		2.44	1.62		2.49	
1900.									
1		3.65	3.60	4.53	4.28	5.00	2.00	3.41	3.50
2		3.59	3.75	3.85	4.30	5.35	.65	3.22	3.53
3		3.78	3.89	4.04	4.33	2.50	.54	3.14	3.53
4		3.60	3.84	4.12	4.27	2.25	.52	3.27	3.60
5		3.57	3.54	4.12	4.15	5.21	.53	2.60	3.60
6		3.59	3.57	4.11	4.04	5.09	.53	2.71	3.61
7		3.70	4.00	4.11	3.62	3.29	.50	2.53	3.66
8		3.97	4.31	4.10	4.07	3.85	.45	2.88	3.59
9		3.59	4.21	4.02	3.94	3.53	.40	2.95	3.88
10		3.89	2.99	3.70	4.28	1.33	.53	2.55	3.75
11		3.87	2.70	4.27	3.93	1.00	3.25	2.68	3.83
12		3.82	2.76	4.47	3.90	1.11	6.55	2.63	3.70
13		3.99	1.47	4.00	3.87	1.05	4.23	2.82	3.75
14		3.76	1.52	4.00	3.36	1.12	4.82	2.20	3.69
15		3.00	1.33	3.83	3.06	3.93	4.52	3.12	3.97
16		4.20	1.53	4.39	4.48	5.25	3.93	3.02	3.80
17		4.27	2.00	4.30	4.58	5.15	3.62	2.63	3.82
18		3.18	2.87	4.32	4.76	5.00	3.52	2.83	3.82
19		3.03	2.60	4.30	4.90	4.98	3.57	2.86	3.72
20		2.89	3.02	4.06	5.13	5.00	3.57	2.63	3.69

Daily center depth, in feet, of mill race on Republican River at Superior—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1900.									
21	.....	3.37	3.57	3.10	5.10	4.85	3.52	3.99	3.30
22	.....	3.15	3.59	3.40	5.11	4.58	3.48	3.92	3.68
23	.....	3.00	3.80	3.38	5.00	4.82	3.58	3.99	3.50
24	.....	3.89	3.95	3.90	5.02	4.87	3.52	3.92	3.95
25	.....	2.29	3.85	4.20	5.12	4.72	3.32	3.95	.....
26	.....	2.80	4.02	4.34	4.92	4.52	2.52	3.89	.....
27	.....	2.78	2.63	4.54	4.90	4.68	2.80	3.78	.....
28	.....	3.20	4.02	4.40	4.60	4.55	2.80	4.02	.....
29	.....	3.30	3.58	4.38	5.27	3.65	3.00	3.80	.....
30	.....	3.60	4.33	4.12	5.40	3.12	3.14	3.62	.....
31	.....	.....	4.05	.....	5.00	3.22	.....	3.55	.....
1901.									
1	.....	3.42	.....	2.82	1.82	1.40	.95	1.10	1.10
2	.....	3.57	.....	2.90	2.22	.61	.90	1.04	1.40
3	.....	3.52	.....	2.92	2.32	.60	1.30	1.02	.62
4	.....	3.57	.....	2.73	2.22	.60	.90	1.00	.64
5	.....	3.58	2.52	2.70	2.12	.61	.90	1.10	.94
6	.....	3.75	3.12	2.82	2.13	.52	4.82	1.00	.62
7	.....	3.75	3.09	2.73	2.20	.50	4.19	1.10	.60
8	.....	3.62	3.11	2.80	2.12	.68	4.40	1.08	.94
9	.....	3.73	2.58	2.72	1.65	.60	4.95	.95	.84
10	.....	3.74	2.42	2.69	1.50	.69	5.00	.95	.53
11	.....	3.80	3.17	2.62	1.18	3.82	6.00	.90	.98
12	.....	3.82	3.29	2.60	.93	3.78	5.65	.96	.90
13	.....	3.67	3.29	2.62	.86	3.70	5.12	.93	.93
14	.....	3.80	3.30	2.71	1.20	3.71	4.80	.90	.90
15	.....	3.99	3.45	3.11	.92	2.13	5.00	.80	.90
16	.....	3.98	2.82	2.40	.58	1.30	4.50	.86	.85
17	.....	3.98	2.90	2.70	.50	1.40	2.19	.88	.50
18	.....	4.02	2.82	3.01	.45	.75	1.90	.86	.90
19	.....	3.76	3.51	2.98	.57	.68	1.85	.82	.90
20	.....	3.91	2.50	3.01	.55	.72	1.80	.60	.90
21	.....	3.78	3.20	3.56	.40	1.11	1.60	.86	.95
22	.....	3.71	2.72	1.00	.33	1.21	1.55	.98	.90
23	.....	3.51	2.50	3.25	.30	1.00	1.45	.75	.98
24	.....	3.40	3.00	3.35	.40	1.72	1.40	.83	.53
25	.....	3.40	2.98	3.17	.30	.80	1.25	.90	1.00
26	.....	3.32	3.02	3.01	.45	.60	1.28	.76	.98
27	.....	3.40	3.00	2.80	.50	.59	1.23	.48	.91
28	.....	.....	2.58	2.63	.55	.55	1.12	.73	1.03
29	.....	.....	2.47	2.35	.40	.48	1.40	.84	.93
30	.....	.....	3.10	2.41	.52	.61	1.25	1.10	.94
31	.....	.....	2.32	.....	2.45	1.11	.....	.92	.....
1903.									
1	.....	4.01	4.13	5.34	3.13	4.75	2.25	4.01	4.50
2	.....	3.85	4.02	4.39	3.00	4.15	2.55	4.00	4.42
3	.....	4.20	4.10	3.83	3.00	3.82	2.22	4.00	4.22
4	.....	3.65	4.01	3.60	2.75	3.80	2.18	3.90	4.43
5	.....	3.62	4.24	3.20	3.10	3.15	2.05	4.15	4.29
6	.....	3.70	4.18	3.08	2.95	2.86	1.89	4.27	4.38
7	.....	3.75	4.19	2.05	4.00	3.00	1.52	4.12	4.30
8	3.20	3.72	5.95	3.70	3.60	2.90	3.40	4.02	4.40
9	7.45	3.70	6.75	3.75	3.32	2.52	3.35	4.12	4.42
10	7.30	3.68	5.80	3.55	3.14	2.48	2.88	3.95	4.27
11	7.65	3.70	6.84	3.40	3.12	2.43	2.96	4.22	4.36
12	7.60	3.85	5.40	3.20	4.96	2.51	2.80	4.03	4.29
13	7.50	3.50	5.00	3.25	5.10	2.80	3.00	4.10	3.72
14	3.60	3.52	4.21	2.60	5.40	3.00	3.32	4.25	3.82
15	3.00	3.58	3.79	3.80	4.95	2.71	3.40	4.12	3.84
16	2.20	3.50	3.72	3.70	4.67	2.55	3.32	4.02	4.06
17	2.05	3.62	2.89	3.20	3.40	2.35	2.52	4.15	3.84
18	1.78	3.50	3.15	3.38	2.90	2.35	3.63	4.25	.....
19	1.63	3.10	3.55	3.81	3.85	2.50	3.70	4.23	4.08
20	1.40	4.00	3.52	3.25	3.05	2.58	3.93	4.26	3.98
21	1.48	4.01	3.56	3.40	2.65	2.61	3.91	4.23	4.05
22	1.38	3.98	3.83	3.48	2.58	2.60	3.90	4.24	4.25
23	2.30	3.95	3.79	3.88	2.42	2.35	3.95	4.15	4.55
24	3.30	3.90	3.65	3.64	1.75	2.38	3.91	4.20	4.42
25	3.20	4.10	7.70	3.70	2.45	2.30	4.00	4.30	4.38

Daily center depth, in feet, of mill race on Republican River at Superior—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1903.									
26	3.10	4.06	6.45	3.92	2.85	2.22	3.86	4.15	4.35
27	3.09	3.94	5.36	4.45	3.40	2.25	4.16	4.15	4.37
28	3.05	3.80	4.80	4.02	3.12	2.90	4.00	4.21	4.42
29	3.02	4.10	6.80	3.50	2.90	3.65	4.03	4.20	4.46
30	4.20	4.15	7.20	3.30	2.82	3.04	4.02	4.25	.....
31	4.23	.....	6.10	.....	2.85	2.60	.....	4.28	.....

Mean daily discharge, in second-feet, of Republican River at Superior, 1896–1903.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Day.	June.	July.	Aug.	Sept.	Oct.	Nov.
1896.							1896.						
1	.....	685	928	282	223	333	17	.....	551	1,395	275	204	512
2	.....	4,300	903	261	204	282	18	.....	570	1,466	406	197	476
3	.....	4,850	864	311	223	373	19	.....	552	1,042	296	191	390
4	.....	.....	467	268	229	342	20	720	532	611	303	204	325
5	.....	3,025	467	216	241	325	21	600	580	580	268	223	357
6	.....	2,147	467	210	229	342	22	530	450	790	296	268	382
7	.....	1,750	1,279	204	210	333	23	551	484	695	311	229	415
8	.....	1,940	730	197	191	415	24	441	450	632	282	217	365
9	.....	1,904	1,816	204	204	406	25	450	441	611	223	229	941
10	.....	1,525	467	268	191	441	26	1,052	423	522	.....	217	1,137
11	.....	1,325	415	325	223	398	27	642	382	467	268	229	450
12	.....	1,165	341	304	193	432	28	673	374	432	254	223	459
13	.....	941	304	289	204	441	29	642	398	365	289	415	.....
14	.....	813	268	423	191	476	30	610	432	333	282	382	493
15	.....	720	261	289	191	442	31	.....	1,004	296	.....	365	.....
16	.....	652	228	289	204	532							

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1897.									
1	.....	.....	665	190	2,360	94	110	.....	.....
2	.....	820	575	180	555	110	85	.....	.....
3	.....	.....	500	220	2,660	94	64	60	.....
4	.....	880	480	220	2,060	90	.....	.....	.....
5	.....	.....	457	180	1,800	100	75	.....	.....
6	.....	.....	475	241	4,310	330	74	.....	.....
7	.....	990	445	370	2,660	1,460	64	.....	.....
8	.....	1,388	420	270	3,000	395	.....	.....	.....
9	.....	1,190	575	230	2,360	390	.....	.....	.....
10	.....	1,074	600	212	1,010	310	.....	.....	.....
11	.....	1,095	470	750	770	305	.....	.....	.....
12	.....	1,190	440	550	506	390	70	.....	.....
13	.....	1,252	420	550	350	375	85	.....	.....
14	.....	1,050	370	370	265	380	60	.....	.....
15	516	1,095	360	220	230	101	64	.....	.....
16	.....	.....	341	270	190	119	241	75	.....
17	385	.....	330	370	190	119	180	.....	.....
18	.....	1,252	305	750	220	140	180	.....	.....
19	.....	1,074	280	750	170	155	125	.....	.....
20	425	990	255	490	230	212	1,330	1,142	.....
21	.....	945	230	405	206	171	82	1,160	.....
22	650	920	250	320	160	206	75	1,130	.....
23	465	740	1,130	290	140	190	.....	1,160	.....
24	.....	880	445	330	165	395	64	.....	.....
25	.....	840	425	226	120	341	70	1,010	.....
26	.....	675	395	.....	165	265	.....	1,070	.....
27	457	620	445	.....	165	212	.....	.....	.....
28	.....	.....	280	.....	640	180	.....	.....	.....
29	.....	.....	270	.....	206	165	.....	.....	.....
30	.....	800	220	.....	131	119	82	.....	.....
31	610	.....	180	.....	119	105	.....	.....	.....

72607—IRR 230—09——13

Mean daily discharge, in second-feet, of Republican River at Superior, 1896–1903—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1898.									
1			500	1,295	511	210		200	320
2			1,310	1,030	540	230		230	330
3			700	1,000	495	215		165	340
4			710	960	345	210		165	370
5			765	1,000	430	210		170	340
6			930	1,240	430	210	410	165	340
7			995	980	420	185	360	185	360
8			1,100	1,720	420	185	305	200	350
9			960	1,380	530	195	360	145	360
10			1,210	1,325	1,345	185	345	195	345
11			980	2,300	1,000	165	350	270	350
12			910	1,625	530	150	410	300	410
13			1,170	1,530	560	155	285	290	415
14			1,310	1,610	910	230	240	280	410
15			740	1,565	725	100	230	270	420
16			910	1,575	560	165	185	330	420
17			870	1,600	540	165	190		470
18			890	1,380	480	150	240		450
19			845	1,600	430	160	210		450
20		590	1,000	1,430	380		210		
21		580	1,465	1,275	345	145	470		
22		940	1,445	1,040	420		410		
23			1,350	1,240	340		380	325	
24		885	930	1,045	340	380	270	295	
25		430	890	910	270	270	275	290	
26		580	1,050	710	295	215	240	295	
27		560	910	750	280	205	220	265	
28		560	1,015	685	270	180	220	330	
29		490	1,870	630	270	200	215	320	
30		520	1,630	560	220		205	365	
31			1,170		230			330	
1899.									
1		737	388	236	906	812	102	27	
2		727	363	274	738	868	78	42	
3		692	396	346	608	650	90	27	
4		682	995	311	574	475	52	54	
5		780	383	268	590	397	49	38	
6		753	366	256	743	320	29	37	
7		842	331	268	837	345	34	52	
8		759	394	262	793	247	43	48	
9		747	417	238	490	238	38	61	
10		728	416	245	412	245	37	61	
11		698	452	228	355	207	66	25	
12		618	442	213	327	231	56	24	
13		623	452	209	355	242	58	45	
14		607	457	493	342	350	61	37	
15		606	451	348	302	247	41	32	
16		480	499	428	319	229	49	78	
17		532	453	266	318	378	6	50	
18		529	418	238	304	306	58	68	
19		522	407	158	287	230	45	74	
20		470	735	152	293	212	47	53	
21		478	1,800	162	371	160	16	101	
22		412	873	141	320	154	49	25	
23		414	587	306	285	156	48	101	
24		425	517	364	215	136	41	40	
25		375	465	241	234	188	45	65	
26		407	544	201	209	258	71	63	
27		434	436	4,036	214	421	60	90	
28		412	410	2,570	238	193	62	78	
29		470	361	1,304	1,384	150	25		
30		385	334	1,174	501	187	31	54	
31			292		316	146		81	
1900.									
1		703	850	532	250	82	49	90	87
2		718	812	367	240	158	12	55	90
3		648	785	408	267	102	10	77	83
4		621	757	306	133	81	8	44	52
5		618	717	349	223	100	10	60	49

Mean daily discharge, in second-feet, of Republican River at Superior, 1896–1903.—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1900.									
6		630	935	345	216	134	9	53	52
7		628	1,073	307	184	47	12	32	36
8		580	2,945	290	132	45	10	45	60
9		565	2,066	256	179	83	8	26	80
10		630	1,306	250	294	267	10	27	90
11		634	1,080	390	225	51	463	36	89
12		665	847	605	180	39	2,010	35	119
13		856	670	674	139	24	450	54	115
14		759	630	457	73	41	244	40	87
15		980	566	390	67	.....	195	42	95
16		1,120	520	430	94	1,278	120	60	162
17		1,370	508	365	102	311	120	43	92
18		1,226	460	340	77	130	140	62	96
19		1,015	438	349	90	195	120	38	102
20		970	418	322	164	177	105	60	112
21		1,396	401	326	142	147	72	130	50
22		1,140	401	410	95	148	54	139	61
23		972	390	450	103	137	73	148	63
24		1,671	419	390	123	118	55	109	160
25		920	470	439	88	71	63	83	.....
26		1,035	421	442	137	36	75	140	.....
27		1,087	404	461	87	100	31	80	.....
28		1,150	370	418	77	63	37	50	.....
29		1,080	365	369	349	50	75	100	.....
30		895	320	315	210	36	34	80	.....
31		.....	342	.....	192	27	.....	89	.....
1901.									
1		650	622	167	154	30	15	515	527
2		637	560	136	154	15	15	1,490	1,030
3		668	530	129	140	10	15	980	377
4		771	527	144	108	5	10	430	370
5		774	552	161	109	5	25	495	442
6		956	555	190	124	5	2,032	375	336
7		900	516	124	89	5	1,657	435	324
8		903	490	133	80	5	1,826	507	442
9		951	469	147	36	5	2,575	525	341
10		974	416	148	31	5	2,237	384	312
11		1,019	393	135	30	856	4,123	384	391
12		1,060	363	138	30	812	4,941	384	370
13		1,045	347	143	20	114	3,247	398	427
14		1,189	325	157	10	112	1,957	363	427
15		1,347	331	301	7	28	2,827	377	370
16		1,507	364	153	5	22	2,115	363	358
17		1,416	390	117	5	18	1,784	384	312
18		1,349	395	170	5	16	462	363	419
19		1,284	379	184	5	10	453	377	391
20		1,296	267	215	5	8	453	305	398
21		1,155	302	465	5	5	433	351	442
22		1,025	272	370	5	5	415	363	391
23		885	265	415	5	5	406	295	442
24		870	239	480	5	5	397	351	312
25		741	206	347	5	10	408	363	442
26		726	206	336	5	10	388	295	442
27		756	216	295	5	10	388	285	427
28		680	218	265	5	10	379	305	469
29		644	250	225	5	10	815	363	427
30		655	146	181	5	10	565	525	406
31		.....	159	.....	119	20	.....	420	.....
1902.									
1		730	400	1,095	3,430	1,920	680	890	635
2		710	335	960	4,525	1,500	520	865	610
3		600	555	1,030	3,690	1,200	570	1,050	635
4		665	470	1,530	1,895	1,490	560	1,370	620
5		620	525	880	4,960	1,050	400	1,775	620
6		590	445	3,235	.....	790	440	1,050	635
7		500	775	3,125	.....	785	370	1,050	660
8		570	950	3,225	12,490	650	315	890	660
9	760	590	1,220	2,230	.....	645	270	890	635
10	740	620	730	1,800	10,460	690	225	845	710

Mean daily discharge, in second-feet, of Republican River at Superior, 1896–1903—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1902.									
11	670	595	570	2,000	5,380	790	260	940	660
12	680	740	510	1,180	3,000	620	240	1,205	460
13	630	570	690	1,110	3,000	480	320	1,995	720
14	690	555	660	835	2,515	690	170	1,125	530
15	670	510	675	1,160	1,750	670	185	830	560
16	650	500	530	690	1,520	600	165	770	570
17	530	580	525	760	1,260	485	155	1,050	510
18	690	520	630	860	2,515	480	255	890	570
19	680	485	2,810	1,920	2,865	385	190	915	510
20	505	570	2,500	1,530	1,265	345	240	830	520
21	455	510	2,120	1,550	1,315	335	225	820	500
22	570	530	1,750	1,315	1,235	335	2,760	735	535
23	630	510	1,290	1,090	1,065	520	10,875	910	685
24	620	510	1,600	990	970	435	4,380	910	970
25	550	485	2,095	830	1,125	330	2,780	860	970
26	655	545	3,115	755	.....	345	2,705	760	620
27	670	460	3,105	690	9,060	450	1,700	650	690
28	920	445	2,365	645	7,665	435	1,310	590	460
29	330	445	2,540	820	2,380	440	1,030	530	570
30	715	390	1,420	320	1,490	540	970	520	.....
31	830	.....	1,425	.....	2,670	455	.....	530	.....
1903.									
1	.....	1,260	845	6,455	910	3,285	700	305	460
2	.....	1,095	935	4,340	760	3,245	520	305	690
3	.....	1,085	1,055	3,610	700	2,165	400	325	520
4	.....	1,065	845	3,115	785	2,695	470	265	525
5	.....	1,055	1,095	2,690	660	1,270	420	295	435
6	.....	1,035	1,150	2,290	630	885	410	295	450
7	.....	935	1,470	2,055	1,900	825	345	285	450
8	.....	950	3,905	2,310	1,360	690	475	245	460
9	.....	1,010	4,530	2,205	1,075	565	525	285	425
10	.....	1,015	6,580	1,600	755	570	455	260	385
11	.....	785	9,515	1,595	2,400	525	410	250	480
12	.....	825	7,095	1,640	4,295	630	365	320	440
13	.....	765	6,400	1,560	5,960	915	320	355	140
14	7,750	765	5,050	1,350	7,825	2,630	480	350	130
15	6,345	930	4,255	1,265	6,455	1,175	405	355	135
16	3,895	935	3,895	1,260	6,040	1,005	355	340	505
17	3,555	895	3,010	1,065	2,285	730	315	355	145
18	3,240	910	2,325	1,075	1,455	695	405	320	220
19	3,085	870	2,155	1,000	3,255	840	445	355	295
20	2,940	705	2,040	915	2,280	835	335	350	315
21	2,140	835	1,690	970	1,575	995	315	350	335
22	2,150	915	2,545	835	1,260	920	405	345	415
23	1,700	840	2,165	1,075	910	590	335	365	535
24	1,770	845	1,890	1,065	770	565	300	355	435
25	1,555	900	11,320	1,170	670	520	305	320	435
26	1,455	765	7,305	1,465	740	520	320	365	480
27	1,470	710	5,160	2,545	640	570	275	355	540
28	1,475	785	3,765	2,165	520	1,580	270	350	645
29	1,380	1,025	14,100	1,690	520	2,840	310	345	570
30	1,295	1,015	13,190	1,260	525	1,680	315	390	510
31	1,260	.....	7,950	.....	465	1,175	.....	355	.....

Mean daily discharge, in second-feet, of Republican River at Bostwick, 1904–1906.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Day.	June.	July.	Aug.	Sept.	Oct.	Nov.
1904.							1904.						
1	.....	1,635	365	335	335	465	17	1,115	1,020	365	110	365	535
2	.....	1,415	335	245	305	535	18	1,165	885	465	85	335	535
3	.....	1,360	335	215	275	570	19	1,470	800	.....	60	365	500
4	.....	2,670	365	275	305	535	20	1,165	760	1,020	110	760	535
5	.....	7,130	400	335	335	535	21	1,470	760	640	85	1,115	535
6	1,115	7,480	570	245	305	535	22	1,210	720	570	110	1,020	535
7	930	2,670	535	275	305	500	23	1,260	720	365	110	1,020	500
8	430	1,810	1,020	245	275	500	24	2,640	640	365	85	975	535
9	845	1,835	930	185	305	535	25	3,260	605	335	110	885	535
10	885	2,965	680	245	275	500	26	4,630	570	305	85	845	535
11	760	2,250	535	245	305	500	27	4,450	535	335	110	800	535
12	760	1,870	465	215	335	500	28	2,890	500	305	185	720	535
13	720	2,055	465	215	305	500	29	2,385	400	245	215	605	535
14	680	1,870	430	160	365	535	30	1,870	400	335	275	535	535
15	1,870	1,470	400	135	335	500	31	.....	365	400	.....	500	.....
16	1,690	1,260	365	110	400	535							

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1905.									
1	.....	888	1,470	2,120	7,480	8,170	560	595	.....
2	.....	888	1,260	2,120	14,020	8,440	560	530	.....
3	.....	930	1,210	3,265	19,100	9,760	1,090	530	.....
4	.....	888	1,162	2,670	24,500	11,060	1,090	530	.....
5	.....	888	1,162	1,635	20,000	6,515	1,090	500	.....
6	.....	888	1,068	1,362	12,310	5,800	1,090	500	.....
7	.....	1,210	1,068	1,260	6,200	6,200	770	500	.....
8	.....	1,115	1,068	1,068	4,770	4,595	630	500	.....
9	.....	1,068	1,115	975	4,340	3,615	630	470	.....
10	.....	975	1,162	1,068	4,510	3,250	1,090	440	.....
11	.....	930	7,130	1,115	3,690	2,830	630	440	.....
12	.....	930	1,415	1,210	2,970	2,260	630	440	.....
13	.....	845	1,750	3,115	2,635	1,970	500	410	.....
14	.....	845	1,810	1,750	2,260	1,650	500	410	.....
15	.....	845	1,932	1,415	2,080	1,500	500	410	.....
16	.....	802	5,610	3,342	2,025	1,650	560	440	.....
17	.....	845	3,265	4,005	1,970	1,805	500	410	.....
18	.....	802	1,932	5,820	1,860	2,025	630	440	.....
19	.....	802	1,692	2,890	1,805	1,700	560	440	.....
20	.....	760	1,415	2,385	3,690	1,315	700	470	.....
21	.....	975	1,210	1,750	1,650	1,180	735	470	.....
22	1,162	802	1,162	1,580	1,550	1,050	700	470	.....
23	1,210	930	1,068	5,210	1,500	970	665	500	.....
24	1,162	1,162	1,162	6,350	1,405	930	735	500	.....
25	1,115	1,310	1,068	7,015	1,315	890	850	500	.....
26	1,115	1,692	975	6,570	6,620	890	810	500	.....
27	1,115	1,525	1,162	5,820	3,040	850	810	500	.....
28	1,020	1,870	975	3,342	2,830	770	770	500	.....
29	1,020	1,750	5,610	2,890	6,000	630	700	500	.....
30	975	1,635	2,965	3,342	4,595	630	665	500	.....
31	930	.....	2,670	.....	5,040	630	.....	500	.....
1906.									
1	.....	.....	3,390	750	.....	460	260	190	630
2	.....	.....	5,130	710	.....	430	260	190	630
3	.....	.....	3,770	710	.....	560	235	170	595
4	.....	.....	3,320	710	.....	830	235	170	595
5	.....	.....	1,920	670	.....	670	210	170	630
6	.....	.....	1,700	670	.....	595	190	210	630
7	.....	590	1,590	595	.....	525	170	235	630
8	.....	705	1,800	560	460	460	150	260	630
9	.....	628	1,700	525	400	460	190	235	630
10	.....	552	1,590	525	370	1,240	190	210	630
11	.....	552	1,440	460	310	1,590	310	190	630
12	.....	515	1,340	430	790	1,290	430	190	630
13	.....	705	1,240	400	340	830	235	210	630
14	.....	1,010	1,190	400	310	710	340	210	630
15	.....	875	1,140	370	310	630	460	235	630

Mean daily discharge, in second-feet, of Republican River at Bostwick, 1904–1906—Con.

Day.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
1906.									
16		705	1,100	370	260	595	285	235	595
17		628	1,050	370	235	490	285	260	595
18		590	1,000	340	210	460	260	260	630
19		552	960	310	210	400	260	285	630
20		552	830	310	260	370	285	310	595
21		552	790	285	525	310	260	370	595
22		515	3,250	285	2,140	310	260	595	560
23		515	1,750	260	2,140	310	260	670	560
24		515	1,290	260	1,750	430	260	630	525
25		480	960	260	1,390	430	235	595	560
26		480	915	285	1,290	340	235	670	595
27		590	750	340	1,240	310	235	790	595
28		788	750	595	1,000	285	210	710	630
29		875	830	750	630	285	210	710	630
30		1,690	790	460	560	285	190	670	630
31			750		525	260		670	

Estimated monthly discharge of Republican River at Superior (1896–1903) and Bostwick (1904–1906).

[Drainage area, 22,300 square miles.]

Month and year.	Discharge in second-feet.			Run-off.				Rainfall (inches).
	Maximum.	Minimum.	Mean.	Total in acre-feet.	Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
March.								
1897	650	385	510	31,300	0.023	0.03	1.9	1.55
1899[a]	956	601	706	43,400				.86
1902[b]	920	330	675	29,400				1.16
1903[c]	7,750	1,260	2,692	96,100				.39
1905[d]	1,210	930	1,082	21,500				1.76
April.								
1897	1,390	620	946	56,300	.042	.05	1.3	3.95
1899	842	375	578	34,400	.026	.03	4.6	.65
1900	1,670	565	909	54,100	.041	.04	.9	4.45
1901	1,510	637	961	57,100	.043	.05	1.5	3.28
1902	740	390	555	33,000	.025	.02	2.3	.86
1903	1,260	705	918	54,600	.041	.05	3.6	1.38
1905	1,870	760	1,060	63,100	.047	.05	1.4	3.70
1906[e]	1,690	480	673	32,000				4.92
May.								
1897	1,130	180	420	25,800	.019	.02	1.6	1.22
1898	1,870	500	1,053	64,800	.047	.06	1.3	4.72
1899	1,800	292	511	31,400	.023	.03	1.0	2.94
1900	2,940	320	735	45,200	.033	.03	2.0	1.50
1901	622	146	364	22,400	.016	.02	2.1	.96
1902	2,810	335	1,269	78,000	.057	.07	1.3	5.52
1903	14,100	845	4,491	276,100	.201	.23	3.2	7.14
1905	7,130	975	1,927	118,500	.086	.10	2.2	4.56
1906	5,130	750	1,610	99,000	.072	.08	4.3	1.87
June.								
1896[f]	1,052	441	627	13,700				3.55
1897[g]	750	180	359	17,100				4.58
1898	2,300	560	1,235	73,500	.055	.06	1.8	3.35
1899	4,040	141	531	31,600	.024	.02	.5	3.74
1900	674	250	392	23,300	.017	.02	.8	2.42
1901	480	117	219	13,000	.010	.01	.3	3.13
1902	3,240	320	1,372	81,600	.061	.07	1.5	4.67
1903	6,460	835	1,921	114,300	.086	.10	5.4	1.85
1904	4,630	430	1,667	99,200	.074	.08	1.4	5.48
1905	7,010	975	2,949	175,500	.132	.15	3.2	4.63
1906	750	260	466	27,700	.021	.02	1.0	2.02

[a] March 19 to 31.
[b] March 9 to 31.
[c] March 14 to 31.
[d] March 22 to 31.
[e] April 7 to 30.
[f] June 20 to 30.
[g] June 1 to 24.

Estimated monthly discharge of Republican River at Superior (1896–1903) and Bostwick (1904–1906)—Continued.

Month and year.	Discharge in second-feet.			Run-off.				Rainfall (inches).
	Maximum.	Minimum.	Mean.	Total in acre-feet.	Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
July.								
1896	4,850	374	1,179	70,200	0.053	0.06	2.2	2.69
1897	4,310	119	922	56,700	.041	.05	2.4	2.12
1898	1,340	220	479	29,400	.021	.02	.9	2.17
1899	1,380	209	458	28,200	.020	.02	.5	3.67
1900	349	67	159	9,800	.007	.01	.3	3.05
1901	154	5	44	2,600	.002	.002	.2	1.10
1902	12,490	970	3,080	189,400	.138	.16	2.9	5.41
1903	7,820	465	1,948	119,800	.087	.10	2.1	4.67
1904	7,480	365	1,656	101,800	.073	.08	2.7	3.23
1905	24,500	1,315	5,734	352,600	.256	.30	4.6	6.53
1906[a]	2,140	210	736	35,000				2.99
August.								
1896	1,810	228	659	40,500	.029	.03	1.1	2.64
1897	1,460	94	259	15,900	.011	.01	.3	3.05
1898	380	100	195	12,000	.009	.01	.7	1.55
1899	868	136	303	18,600	.014	.02	1.1	1.79
1900	1,280	24	149	9,200	.007	.01	.4	2.28
1901	856	5	70	4,300	.003	.003	.1	3.35
1902	1,920	330	674	41,400	.030	.03	1.3	2.35
1903	3,280	520	1,230	75,600	.055	.06	1.7	3.61
1904	1,020	245	475	22,800	.021	.02	.9	2.82
1905	11,060	630	3,082	189,500	.138	.16	8.1	1.98
1906	1,590	260	553	34,000	.025	.03	1.0	2.89
September.								
1896	423	197	279	16,000	.012	.01	.5	1.87
1897	1,330	60	149	8,900	.007	.01	.7	1.40
1898	470	185	289	17,200	.013	.01	.2	4.13
1899	102	6	50	3,000	.002	.002	.9	.22
1900	2,010	8	156	9,300	.007	.01	.7	1.54
1901	4,990	10	1,246	74,100	.055	.06	1.5	3.97
1902	10,880	155	1,175	70,000	.052	.06	1.5	4.01
1903	700	270	389	23,100	.017	.02	3.8	.53
1904	335	60	180	10,700	.008	.01	.4	1.83
1905	1,090	500	725	43,100	.032	.04	1.5	2.45
1906	460	150	253	15,100	.011	.01	.5	2.04
October.								
1896	415	191	230	14,100	.010	.01	.8	1.44
1898	365	145	264	16,200	.012	.01	1.1	.88
1899	101	24	53	3,300	.002	.002	.5	.42
1900	148	26	69	4,200	.003	.003	.3	.87
1901	1,490	285	443	27,200	.020	.02	2.7	.75
1902	1,990	520	937	57,600	.042	.05	2.3	2.22
1903	390	245	326	20,000	.015	.02	1.6	1.08
1904	1,110	275	513	31,500	.023	.03	1.1	2.61
1905	595	410	479	29,400	.021	.02	2.0	1.03
1906	790	170	371	22,800	.017	.02	.8	2.53
November.								
1896	1,140	282	449	25,800	.020	.02	3.7	.59
1898[b]	470	320	382	22,700				.55
1900[c]	162	36	87	5,200				.24
1901	1,030	312	419	24,900	.019	.02	7.5	.28
1902	970	460	622	37,000	.028	.03	22.4	.14
1903	690	130	417	24,800	.019	.02	3.0	.70
1904	570	465	523	31,100	.023	.03	43.0	.07
1906	630	525	610	36,300	.027	.03	4.5	.67

[a] July 8 to 31. [b] November 1 to 19. [c] November 1 to 24.

SOUTH FORK OF REPUBLICAN RIVER NEAR BENKELMAN.

A station was established on the South Fork of the Republican about three-fourths of a mile east of Benkelman, November 1, 1894, discontinued September 5, 1895, and reestablished May 20, 1903. It

is located at the highway bridge, on the line between secs. 17 and 20, T. 1 N., R. 37 W.

At the gaging section the river is straight and the bed is composed of shifting sand. The banks are low, but seldom overflow. The channel is somewhat obstructed by piling of the bridge. The water is never sluggish, even at low stages. The range of gage heights is about 4 feet.

Measurements are made from a pile bridge, the upstream hand rail of which is marked at 5-foot intervals.

The gage is a vertical staff, 5½ feet long, spiked to the upstream side of the first bent in the channel from the right bank of the stream. It is referred to bench marks as follows: (1) The top of the south end of the concrete foundation for the first upright bent of the elevated track in the Burlington and Missouri River Railroad yards, the same as bench mark No. 1 for Republican River at this point; elevation, 18.29 feet above the zero of the gage. (2) The top of the upstream end of the first bent from the left end of the bridge; elevation, 6.62 feet above the zero of the gage.

Discharge measurements of South Fork of Republican River near Benkelman, 1894–1906.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
1894.		*Feet.*	*Sec.-ft.*	1904.		*Feet.*	*Sec.-ft.*
December 9	O. V. P. Stout		1	June 16	J. C. Stevens	1.70	145
1895.				December 7	Jas. A. Green	1.32	32
March 23	do	1.89		1905.			
June 4	do		348	March 21	H. C. Gardner	1.77	140
June 24	do	1.50	75	May 2	do	1.65	111
July 3	do	2.60	278	June 6	do	1.30	34
August 7	do	1.75	22	July 5	do	1.40	51
				July 31	G. W. Bates	1.45	72
1903.				August 28	H. C. Gardner		0
May 20	J. C. Stevens	1.15	58	September 28	F. S. Dobson	1.20	21
September 7	do	0.76	2	1906.			
1904.				May 11	do	1.50	75
April 3	do	1.70	142	June 19	Arthur Dobson	1.00	0
April 18	Adna Dobson	1.10	14	August 25	do		0
June 16	J. C. Stevens	1.70	142	November 30	do	1.48	45

Mean daily gage height, in feet, of South Fork of Republican River near Benkelman, 1894–1906.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day	Nov.	Dec.
1894.			1894.			1894.			1894.		
1	0.97	1.06	9	1.06		17	1.08	1.07	25	1.07	1.54
2	1.06	1.06	10	1.06		18	1.08	1.08	26	1.06	1.31
3	1.06	1.06	11	1.06		19	1.07	1.26	27	1.06	1.12
4	1.05	1.06	12	1.06		20	1.08	1.24	28	1.07	1.09
5	1.05	1.06	13	1.06		21	1.08	1.54	29	1.06	1.09
6	1.05	1.06	14	1.06		22	1.07	1.52	30	1.06	1.09
7	1.06	1.06	15	1.06		23	1.07	1.51	31		1.08
8	1.06	1.06	16	1.08	1.07	24	1.08	1.43			

Mean daily gage height, in feet, of South Fork of Republican River near Benkelman, 1894–1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1895.												
1	1.06	1.42	2.42	1.87	1.65	1.88	1.34	1.90	.....	.....	.....	.....
2	1.06	1.54	2.13	1.92	1.63	.....	3.12	1.90	.....	.....	.....	.....
3	1.06	1.56	2.12	1.86	1.56	.....	2.70	1.89	.....	.....	.....	.....
4	1.06	1.68	2.12	1.83	1.45	.....	2.30	1.89	.....	.....	.....	.....
5	1.06	1.74	2.09	1.78	1.43	.....	2.01	1.89	.....	.....	.....	.....
6	1.23	0.00	2.07	1.79	1.42	.....	1.90	1.88	.....	.....	.....	.....
7	1.25	1.97	1.97	2.17	1.41	.....	1.80	1.75	.....	.....	.....	.....
8	1.26	1.86	1.96	2.06	1.40	.....	1.89	1.68	.....	.....	.....	.....
9	1.56	1.64	1.94	1.99	1.39	.....	1.80	1.68	.....	.....	.....	.....
10	1.58	1.59	1.89	1.89	1.40	.....	1.80	1.65	.....	.....	.....	.....
11	1.63	1.39	2.11	1.86	1.39	.....	1.89	1.03	.....	.....	.....	.....
12	1.60	1.36	1.94	1.79	1.36	.....	1.89	1.60	.....	.....	.....	.....
13	1.74	1.32	1.63	1.74	1.39	.....	2.00	1.58	.....	.....	.....	.....
14	1.73	1.26	1.64	1.70	1.36	.....	3.12	1.55	.....	.....	.....	.....
15	1.76	1.23	1.66	1.72	1.37	.....	2.88	1.55	.....	.....	.....	.....
16	1.76	1.23	1.68	1.82	1.36	.....	2.30	1.55	.....	.....	.....	.....
17	1.79	1.25	1.95	1.88	1.37	.....	2.20	1.54	.....	.....	.....	.....
18	1.85	1.29	2.12	1.84	1.37	.....	2.10	1.54	.....	.....	.....	.....
19	1.82	1.29	2.09	1.77	1.37	.....	2.01	1.54	.....	.....	.....	.....
20	2.00	2.13	2.05	1.75	1.36	.....	2.12	1.54	.....	.....	.....	.....
21	2.06	2.14	1.99	1.71	1.35	[a]1.50	2.20	1.58	.....	.....	.....	.....
22	2.09	2.24	1.98	1.71	1.35	1.50	2.30	1.50	.....	.....	.....	.....
23	2.19	2.29	1.89	1.70	1.35	1.45	2.60	1.50	.....	.....	.....	.....
24	2.04	2.34	1.89	1.74	1.36	1.50	2.30	1.50	.....	.....	.....	.....
25	1.68	2.37	1.90	1.68	1.37	1.45	2.30	.....	.....	.....	.....	.....
26	1.68	2.39	1.87	1.61	1.39	1.45	2.05	.....	.....	.....	.....	.....
27	1.67	2.54	1.83	1.58	1.37	1.45	2.04	.....	.....	.....	.....	.....
28	1.61	2.68	1.83	1.70	1.37	1.40	2.00	.....	.....	.....	.....	.....
29	1.59	.....	1.78	1.88	1.37	1.40	1.90	.....	.....	.....	.....	.....
30	1.54	.....	1.69	1.76	1.55	1.40	1.89	.....	.....	.....	.....	.....
31	1.44	.....	1.73	.....	2.27	.....	1.89	.....	.....	.....	.....	.....
1903.												
1	.....	.....	.....	.....	.....	1.05	.80	.98	0.80	0.90	1.20	1.20
2	.....	.....	.....	.....	.....	1.05	.80	1.30	.80	.90	1.15	1.20
3	.....	.....	.....	.....	.....	1.05	.80	1.10	.80	.90	1.15	1.15
4	.....	.....	.....	.....	.....	1.05	.85	1.00	.80	1.00	1.15	1.05
5	.....	.....	.....	.....	.....	1.05	.90	.95	.80	.90	1.10	1.10
6	.....	.....	.....	.....	.....	1.05	.80	.90	.80	.90	1.15	1.10
7	.....	.....	.....	.....	.....	1.20	.80	.90	.80	.90	1.10	1.20
8	.....	.....	.....	.....	.....	1.20	.80	.90	.80	1.00	1.15	1.30
9	.....	.....	.....	.....	.....	1.20	.80	.85	(a)	1.00	1.15	1.30
10	.....	.....	.....	.....	.....	1.20	.80	1.00	(a)	1.00	1.15	1.40
11	.....	.....	.....	.....	.....	1.20	.80	.85	(a)	1.00	1.15	1.30
12	.....	.....	.....	.....	.....	1.15	.95	.80	(a)	1.00	1.20	1.10
13	.....	.....	.....	.....	.....	1.10	1.00	.80	(a)	1.00	1.15	1.15
14	.....	.....	.....	.....	.....	1.05	.80	1.00	.85	1.05	1.15	1.25
15	.....	.....	.....	.....	.....	1.05	1.00	1.00	.85	1.05	1.15	1.30
16	.....	.....	.....	.....	.....	1.00	1.00	1.10	.85	1.00	1.10	1.30
17	.....	.....	.....	.....	.....	1.00	.95	1.00	.85	1.05	1.20	1.40
18	.....	.....	.....	.....	.....	1.00	.90	1.00	.85	1.05	1.20	1.40
19	.....	.....	.....	.....	.....	1.00	.90	1.00	.85	1.05	1.10	1.40
20	.....	.....	.....	.....	1.15	.95	.95	1.00	.85	1.00	1.15	1.45
21	.....	.....	.....	.....	1.15	.95	.90	.90	.85	1.05	1.10	1.40
22	.....	.....	.....	.....	1.10	.90	.90	.90	.85	1.05	1.30	1.35
23	.....	.....	.....	.....	1.10	.90	.85	.85	.85	1.05	1.40	1.25
24	.....	.....	.....	.....	1.10	.90	.80	.80	.90	1.10	1.30	1.70
25	.....	.....	.....	.....	1.05	.90	.80	.85	.90	1.10	1.20	1.70
26	.....	.....	.....	.....	1.15	.90	.80	.80	.80	1.10	1.20	1.40
27	.....	.....	.....	.....	1.05	.85	.80	.80	.90	1.10	1.25	1.40
28	.....	.....	.....	.....	1.05	.80	.80	.80	.90	1.10	1.25	1.50
29	.....	.....	.....	.....	1.00	.80	.80	.80	.90	1.10	1.20	1.50
30	.....	.....	.....	.....	1.05	.80	.80	.80	.90	1.10	1.10	1.40
31	.....	.....	.....	.....	1.10	.....	.80	.80	.....	1.10	.....	1.40
1904.												
1	1.30	.....	1.35	1.20	1.50	1.50	1.35	1.00	1.05	1.30	1.50	1.30
2	1.50	.....	1.40	1.15	1.55	1.55	1.40	1.50	1.05	1.25	1.50	1.30
3	1.40	.....	1.30	1.20	1.50	1.60	1.50	1.00	1.05	1.25	1.50	1.30
4	1.30	.....	1.40	1.20	1.50	1.40	1.55	1.20	1.00	1.30	1.50	.....
5	1.30	.....	1.55	1.20	1.70	1.60	1.40	1.10	1.00	1.30	1.50	.....

[a] On June 21 a new gage rod was erected to replace the one washed out June 1.

Mean daily gage height, in feet, of South Fork of Republican River near Benkelman, 1894–1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.												
6	1.40	.....	1.50	1.20	1.50	1.55	1.50	.....	1.00	1.25	1.50	.....
7	1.40	.....	1.35	1.00	1.50	1.50	1.30	.....	1.00	1.30	1.50	1.32
8	1.40	.....	1.40	.....	1.50	1.45	.....	1.00	1.00	1.40	1.45	.....
9	1.40	.....	1.40	1.00	1.40	1.60	1.60	1.50	1.00	1.30	.....	.....
10	1.40	.....	1.40	1.05	1.45	1.75	1.55	1.40	1.00	1.40	1.40	.....
11	1.55	.....	1.30	1.10	1.40	2.15	1.50	1.30	1.00	1.40	1.50	.....
12	1.60	.....	1.40	1.10	1.35	1.80	1.20	1.10	1.00	1.30	1.50	.....
13	1.40	.....	1.40	1.15	1.40	1.80	1.30	1.10	1.00	1.30	1.50	.....
14	1.30	.....	1.40	1.00	1.40	1.80	1.30	1.10	1.00	1.25	1.50	.....
15	1.40	.....	1.40	.95	1.40	1.80	1.10	1.10	1.00	1.25	1.45	.....
16	1.40	.....	1.40	1.00	1.40	1.60	1.10	1.10	.....	1.25	1.45	.....
17	1.45	.....	1.40	.95	1.40	1.80	1.05	1.05	1.00	1.30	1.50	.....
18	1.50	.....	1.40	.90	1.40	1.80	1.00	1.10	.85	.....	1.45	.....
19	1.40	.....	1.40	.95	1.40	2.30	1.05	1.10	.85	1.70	1.45	.....
20	1.50	.....	1.40	.95	1.30	1.30	1.10	1.00	.85	1.70	1.45	.....
21	1.40	.....	1.40	.95	1.40	1.50	.90	.....	.85	1.60	1.45	.....
22	1.40	.....	1.40	1.05	1.50	1.55	.90	1.15	.85	1.50	1.50	.....
23	1.35	.....	1.30	1.00	1.50	1.70	.90	1.10	.85	1.50	1.40	.....
24	.....	.....	1.25	.....	2.00	2.00	1.10	1.05	.85	1.50	1.45	.....
25	.....	.....	1.30	1.20	1.70	1.45	1.10	1.05	1.00	1.35	1.45	.....
26	.....	.....	1.20	1.20	1.60	1.45	1.00	1.05	1.00	1.40	1.45	.....
27	.....	.....	1.25	1.30	1.80	1.40	.80	1.05	1.00	1.35	1.45	.....
28	.....	1.40	1.35	1.20	1.60	1.40	.80	1.05	.....	1.50	.....	.....
29	.....	1.40	1.30	1.20	1.50	1.30	.80	1.05	1.30	1.50	.....	.....
30	.....	.....	1.25	1.40	1.50	1.30	.85	1.05	1.30	1.55	1.40	.....
31	.....	.....	1.25	.....	1.45	.....	.85	1.05	.....	1.50	.....	.....
1905.												
1	.....	.....	.....	1.85	1.7	1.65	1.6	1.6	.....	.....	.....	.....
2	.....	.....	.....	1.9	1.65	1.55	1.55	1.5	.....	.....	.....	.....
3	.....	.....	.....	2.05	1.65	1.5	1.6	1.5	.....	.....	.....	.....
4	.....	.....	.....	1.95	1.7	1.45	1.5	1.5	.....	.....	.....	.....
5	.....	.....	.....	1.9	1.7	1.35	1.4	1.4	1.35	.....	.....	.....
6	.....	.....	.....	1.8	1.6	1.35	1.4	1.35	.....	.....	.....	.....
7	.....	.....	.....	1.75	1.6	1.3	1.4	1.3	.....	.....	.....	.....
8	.....	.....	.....	1.75	1.6	1.25	1.35	1.25	.....	.....	.....	.....
9	.....	.....	.....	1.75	1.65	1.35	1.35	1.25	.....	.....	.....	.....
10	.....	.....	.....	1.75	1.7	1.85	1.25	1.2	1.45	.....	.....	.....
11	.....	.....	.....	1.75	1.7	1.6	1.2	1.25	.....	.....	.....	.....
12	.....	.....	.....	1.55	1.7	1.55	1.2	1.25	.....	.....	.....	.....
13	.....	.....	.....	1.5	1.5	1.35	1.15	1.3	.....	.....	.....	.....
14	.....	.....	.....	1.4	1.55	1.35	1.1	.....	.....	.....	.....	.....
15	.....	.....	.....	1.4	1.55	1.3	1.0	.....	.....	.....	.....	.....
16	.....	.....	.....	1.4	1.55	1.35	1.1	.....	.....	.....	.....	.....
17	.....	.....	2.1	1.5	1.5	2.2	1.0	.....	.....	.....	.....	.....
18	.....	.....	1.95	1.45	1.45	1.7	1.1	1.55	.....	.....	.....	.....
19	.....	.....	2.1	1.45	1.6	1.6	1.0	.....	1.5	.....	.....	.....
20	.....	.....	1.95	1.55	1.7	1.55	1.0	.....	1.5	.....	.....	.....
21	.....	.....	1.85	1.6	1.4	1.2	1.1	.....	.....	.....	.....	.....
22	.....	.....	1.8	1.5	1.75	1.55	1.15	.....	.....	.....	.....	.....
23	.....	.....	1.8	1.8	1.45	1.45	1.1	.....	.....	.....	.....	.....
24	.....	.....	1.8	2.1	1.45	1.45	1.1	.....	.....	.....	.....	.....
25	.....	.....	1.75	2.25	1.45	1.35	1.1	.....	.....	1.35	.....	.....
26	.....	.....	1.7	2.05	1.65	1.35	1.1	.....	.....	1.35	.....	.....
27	.....	.....	1.6	2.05	1.65	1.35	1.05	.....	.....	1.4	.....	.....
28	.....	.....	1.7	2.0	1.6	1.25	1.1	.....	.....	1.45	.....	.....
29	.....	.....	1.7	1.8	1.75	1.25	1.2	.....	.....	1.5	.....	.....
30	.....	.....	1.7	1.75	1.65	1.25	1.8	.....	.....	1.55	.....	.....
31	.....	.....	1.78	.....	1.75	.....	1.7	.....	.....	1.6	.....	.....
1906.												
1	.....	.....	.....	1.75	2.00	1.40	.95	1.00	.90	1.00	1.45	.....
2	.....	.....	.....	1.70	1.95	1.40	.95	1.00	.90	1.00	1.50	.....
3	.....	.....	.....	1.70	1.95	1.35	.95	1.00	.90	1.00	1.50	.....
4	.....	.....	.....	1.70	1.95	1.30	.....	1.00	.90	1.00	1.50	.....
5	.....	.....	.....	1.60	1.90	1.25	.95	1.00	.90	1.00	.....	.....
6	.....	.....	.....	1.60	1.80	1.20	.95	1.00	.90	1.00	1.50	.....
7	.....	.....	.....	1.65	1.70	1.15	.95	1.00	.95	.95	1.45	.....
8	.....	.....	.....	1.60	1.70	1.10	.95	1.00	.95	1.00	1.45	.....
9	.....	.....	.....	1.60	1.70	1.05	.95	1.00	.95	.95	.....	.....
10	.....	.....	.....	1.55	1.60	1.05	.95	1.00	.95	1.00	1.50	.....

Mean daily gage height, in feet, of South Fork of Republican River near Benkelman, 1894–1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906.												
11					1.50	1.00	0.95	1.00	0.95	1.00	1.50	
12					1.50	1.00	.95	.90	.90	1.00	1.40	
13				1.60	1.50	1.00		.90	.90			
14				1.60	1.50	1.00	.95	.90			1.45	
15				1.60	1.50	1.00	.95	.90		1.00	1.45	
16				1.50	1.50		.95	.90	.95	1.20	1.45	
17					1.45	1.00	.95	.90	.95	1.20	1.50	
18				1.60	1.40	1.00	.90	.90	1.00	1.20	1.50	
19				1.60		1.00	.90	.90	1.00	1.25		
20				1.70		1.00	.90	1.00	1.00	1.25		
21				1.70	1.50	.95	.90	.90	.95			
22				1.70	1.45		.90	.90	1.00			
23				1.65		1.00	.90		.95	1.60	1.60	
24				1.65	1.60	1.00	.90	1.00	1.00	1.50	1.50	
25				1.70	1.60	1.00	.90		1.00	1.60	1.50	
26				1.60	1.50				1.00		1.55	
27				2.30	1.50		1.90	.95	1.00	1.60	1.55	
28				2.30	1.50		1.20	.95	1.00	1.55		
29				2.20	1.45	1.00		.90	1.00	1.55	1.55	
30					1.40	.95		.90	.95	1.55	1.50	
31					1.40		1.10	.95		1.50		

Mean daily discharge, in second-feet, of South Fork of Republican River near Benkelman, 1903–1906.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1903.								1903.							
1		43	7	36	7	22	65	17		36	29	36	15	43	65
2		43	7	79	7	22	57	18		36	22	36	15	43	65
3		43	7	50	7	22	57	19		36	22	36	15	43	50
4		43	15	36	7	36	57	20	57	29	29	36	15	36	57
5		43	22	29	7	22	50	21	57	29	22	22	15	43	
6		43	7	22	7	22	57	22	50	22	22	22	15	43	
7		65	7	22	7	22	50	23	50	22	15	15	15	43	
8		65	7	22	7	36	57	24	50	22	7	7	22	50	
9		65	7	15		36	57	25	43	22	7	15	22	50	
10		65	7	36		36	57	26	57	22	7	7	7	50	
11		65	7	15		36	57	27	43	15	7	7	22	50	
12		57	29	7		36	65	28	43	7	7	7	22	50	
13		50	36	7		36	57	29	36	7	7	7	22	50	
14		43	7	36	15	43	57	30	43	7	7	7	22	50	
15		43	36	36	15	43	57	31	50		7	7		50	
16		36	36	50	15	36	50								

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.										
1	57	31	89	89	57	11	15	47	66	31
2	66	25	102	102	66	89	15	39	66	31
3	47	31	89	115	89	11	15	39	66	31
4	66	31	89	66	102	31	11	47	66	
5	102	31	145	115	66	19	11	47	66	
6	89	31	89	102	89	16	11	39	66	
7	57	11	89	89	47	14	11	47	66	32
8	89	11	89	78	81	11	11	66	57	
9	66	11	66	115	115	89	11	47	52	
10	66	15	78	161	102	66	11	66	47	
11	47	19	66	323	89	47	11	66	66	
12	66	19	57	178	31	19	11	47	66	
13	66	15	66	178	47	19	11	47	66	
14	66	11	66	178	47	19	11	39	66	
15	66	8	66	178	19	19	11	39	57	
16	66	11	66	115	19	19	11	39	57	
17	66	8	66	178	15	15	11	31	66	
18	66	6	66	178	11	19	5	73	57	
19	66	8	66	397	15	19	5	115	57	
20	66	8	47	47	11	11	5	115	57	

Mean daily discharge, in second-feet, of South Fork of Republican River near Benkelman, 1903–1906—Continued.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.										
21	66	8	66	89	6	18	5	89	57	.....
22	66	15	89	102	6	25	5	66	66	.....
23	47	11	89	145	6	19	5	66	47	.....
24	39	21	255	255	19	15	5	66	57	.....
25	47	31	145	78	19	15	11	39	57	.....
26	31	31	115	78	19	15	11	47	57	.....
27	39	47	178	66	5	15	11	39	57	.....
28	57	31	115	66	5	15	29	66	54	.....
29	47	31	89	47	5	15	47	66	50	.....
30	39	66	89	47	5	15	47	78	47	.....
31	39	.....	78	.....	5	15	.....	66	.....	.....

Day.	April.	May.	June.	July.	August.	Day.	March.	April.	May.	June.	July.
1905.						1905.					
1	167	123	109	96	96	17	249	73	73	283	5
2	183	109	84	84	73	18	199	62	62	123	10
3	232	109	73	96	73	19	249	62	96	96	5
4	199	123	62	73	73	20	199	84	123	84	5
5	183	123	43	52	52	21	167	96	52	21	10
6	152	96	43	52	43	22	152	73	137	84	15
7	137	96	35	52	35	23	152	152	62	62	10
8	137	96	28	43	28	24	152	249	62	62	10
9	137	109	43	35	28	25	137	300	62	43	10
10	137	123	167	28	21	26	123	232	109	43	10
11	137	123	96	21	28	27	96	232	109	43	7
12	84	123	84	21	35	28	123	215	96	28	10
13	73	73	43	15	35	29	123	152	137	28	21
14	52	84	43	10	.....	30	123	137	109	28	152
15	52	84	35	5	.....	31	140	.....	137	.....	123
16	52	84	43	10	.....						

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1906.								
1	137	215	.52	0	0	0	0	42
2	123	199	52	0	0	0	0	48
3	123	199	43	0	0	0	0	48
4	123	199	35	0	0	0	0	48
5	96	183	28	0	0	0	0	48
6	96	152	21	0	0	0	0	48
7	109	123	15	0	0	0	0	42
8	96	123	10	0	0	0	0	42
9	96	123	5	0	0	0	0	45
10	84	96	5	0	0	0	0	48
11	88	73	.5	0	0	0	0	48
12	92	72	.5	0	0	0	0	36
13	96	73	.5	0	0	0	0	39
14	96	73	.5	0	0	0	0	42
15	96	73	.5	0	0	0	0	42
16	73	73	.5	0	0	0	17	42
17	84	62	.5	0	0	0	17	48
18	96	52	.5	0	0	0	17	48
19	96	62	.5	0	0	0	21	50
20	123	62	.5	0	0	0	21	53
21	123	73	0	0	0	0	34	55
22	123	62	0	0	0	0	47	58
23	109	79	0	0	0	0	61	61
24	109	96	0	0	0	0	48	48
25	123	96	0	0	0	0	61	48
26	96	73	0	92	0	0	61	54
27	317	73	0	183	0	0	61	54
28	317	73	0	21	0	0	54	54
29	283	62	0	18	0	0	54	54
30	249	52	0	14	0	0	54	48
31	.....	52	.....	10	0	.....	48	.....

Estimated monthly discharge of South Fork of Republican River near Benkelman, 1903–1906.

[Drainage area, 5,910 square miles.]

Month and year.	Discharge in second-feet.			Run-off.				Rainfall (inches).
	Maximum.	Minimum.	Mean.	Total in acre-feet.	Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
March.								
1904	102	31	60	3,690	0.011	0.01	4.0	0.25
1905[a]	249	96	159	4,730				2.77
April.								
1904	66	6	21	1,260	.004	.004	.1	4.00
1905	300	52	141	8,390	.024	.03	.8	3.72
1906	317	73	129	7,680	.022	.02	.5	3.72
May.								
1903[b]	57	36	48	1,140				1.00
1904	255	47	92	5,680	.016	.02	.5	4.26
1905	137	52	100	6,150	.017	.02	.6	3.22
1906	215	52	99	6,100	.017	.02	2.1	.95
June.								
1903	65	7	37	2,200	.006	.01	.5	2.10
1904	397	47	132	7,850	.022	.02	.4	4.50
1905	283	21	68	4,080	.012	.01	.3	3.57
1906	52	0	9	537	.002	.002	.1	1.44
July.								
1903	36	7	15	922	.002	.002	.1	2.65
1904	115	5	39	2,420	.007	.01	.6	1.65
1905	152	5	35	2,180	.006	.01	.3	3.89
1906	183	0	10.9	670	.002	.002	.1	3.27
August.								
1903	79	7	25	1,540	.004	.005	.2	3.12
1904	89	11	24	1,480	.004	.005	.4	1.28
1905[c]	96	21	48	1,230				1.40
1906	0	0	0	0	0	0	0	2.36
September.								
1903[d]	22	7	15	655				.35
1904	47	5	13	774	.002	.002	2.0	.10
1906	0	0	0	0	0	0	0	2.36
October.								
1903	50	22	39	2,400	.006	.01	10.0	.10
1904	66	47	59	3,530	.010	.01	.9	1.07
1906	61	0	21.8	1,340	.004	.004	.3	1.23
November.								
1903[e]	65	50	57	2,260				.36
1904	66	47	59	3,530	.010	.01		0
1906	61	36	48	2,860	.081	.01	3.0	.33

[a] March 17 to 31.
[b] May 20 to 31.
[c] August 1 to 13.
[d] September 1 to 8 and 14 to 30.
[e] November 1 to 20.

FRENCHMAN RIVER AT WAUNETA.

A station established about 100 yards below Wauneta mill and Wauneta Falls, August 8, 1895, was maintained until September 26, 1896.

The bed of the stream at this point is composed of sand and silt, and is continually shifting.

Measurements were made from a highway bridge or by wading.

The gage was a vertical staff attached to the upright piling of the south bent of the bridge. It was referred to bench marks, as follows: (1) The stone doorstep of a concrete house below the gage on the

right bank; elevation, 20.99 feet above the zero of the gage. (2) The top of a stake at the northwest corner of the lot in which the concrete house stands; elevation, 20.33 feet above the zero of the gage.

The estimates of discharge are not as satisfactory as could be desired, owing to the changeable character of the bed and banks.

Discharge measurements of Frenchman River at Wauneta, 1895–96.

Date.	Hydrographer.	Gage height.	Discharge.
1895.		*Feet.*	*Sec.-ft.*
August 9	O. V. P. Stout	1.40	61
September 10	do	.92	56
1896.			
May 15	C. E. Crownover	2.20	85
June 18	O. V. P. Stout	1.84	48
July 14	E. T. Youngfeldt	2.15	91
August 12	O. V. P. Stout	1.90	46
September 16	E. T. Youngfeldt	2.07	85
October 17	C. E. Crownover	2.00	62

Mean daily gage height, in feet, of Frenchman River at Wauneta, 1895–96.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1895.						1895.					
1		0.82	1.14	1.06	1.04	17	1.28	0.94	1.08	1.06	1.10
2		.84	1.12	1.06	1.08	18	1.22	.96	1.08	1.06	1.10
3		.84	1.12	1.06	1.06	19	1.20	1.00	1.08	1.06	1.10
4		.84	1.16	1.06	1.08	20	1.16	.98	1.08	1.05	1.10
5		.84	1.16	1.06	1.12	21	1.14	.98	1.10	1.06	1.10
6		1.88	1.22	1.06	1.16	22	1.12	1.00	1.08	1.06	1.10
7		.90	1.20	1.06	1.16	23	1.10	1.04	1.08	1.06	1.10
8		.92	1.18	1.06	1.24	24	1.10	1.10	1.08	1.06	1.10
9		.92	1.16	1.06	1.28	25	1.08	1.10	1.08	1.08	1.10
10		.92	1.16	1.06	1.16	26	1.08	1.08	1.08	1.10	1.16
11	1.68	.92	1.14	1.06	1.12	27	1.10	1.08	1.06	1.32	1.16
12	1.66	.92	1.14	1.06	1.12	28	1.14	1.08	1.06	1.24	1.16
13	1.42	.94	1.12	1.06	1.12	29	1.16	1.14	1.06	1.16	1.12
14	1.49	1.94	1.12	1.06	1.12	30	1.16	1.16	1.06	1.08	1.10
15	1.36	.94	1.12	1.06	1.12	31	1.18		1.06		1.10
16	1.30	.94	1.10	1.06	1.12						

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
1896.									
1	1.10	1.16	1.12	1.16	2.00	1.16			1.08
2	1.08	1.16	1.12	1.14	1.18	1.14			1.08
3	1.08	1.16	1.14	1.12	1.16	1.14			1.07
4	1.08	1.14	1.14	1.12	1.16	1.14			1.07
5	1.12	1.14	1.16	1.12	1.18	1.12			1.07
6	1.16	1.16	1.16	1.14	1.18	1.12			1.08
7	1.16	1.14	1.16	1.14	1.16	1.12			1.08
8	1.16	1.16	1.16	1.14	1.16	1.12			1.07
9	1.16	1.14	1.14	1.12	1.16	1.10			1.08
10	1.16	1.16	1.14	1.12	1.14	1.10			1.09
11	1.16	1.16	1.14	1.12	1.14	1.08			1.09
12	1.16	1.16	1.12	1.12	1.14	1.08			2.00
13	1.16	1.16	1.12	1.12	1.14	1.04			2.01
14	1.14	1.16	1.00	1.12	1.12	0	2.16		2.01
15	1.14	1.16	1.14	1.14	1.12	.10			2.02
16	1.12	1.16	1.14	1.14	1.12	.12		2.00	2.02
17	1.12	1.16	1.12	1.16	1.12	.14		2.00	2.02
18	1.12	1.12	1.12	1.16	1.12	.16		1.09	2.01
19	1.12	1.12	1.12	1.16	1.10	.16		2.02	2.02
20	1.16	1.14	1.12	1.16	1.10	.08		2.00	2.02
21	1.16	1.14	1.12	1.16	1.12	.16		1.09	2.01
22	1.16	1.16	1.14	1.16	1.12	1.14		1.09	2.01
23	1.14	1.16	1.14	1.14	1.12	1.16		1.08	2.01
24	1.12	1.16	1.14	1.14	1.12	1.16		1.08	2.01
25	1.12	1.16	1.12	1.14	1.12	1.14		1.09	2.01

Mean daily gage height, in feet, of Frenchman River at Wauneta, 1895–96—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
1896.									
26	1.14	1.14	1.12	1.14	1.12	1.14	.....	1.09	2.02
27	1.14	1.12	1.14	1.12	1.12	.....	.....	1.08	.....
28	1.14	1.12	1.14	1.12	1.10	.....	.....	1.08	.....
29	1.14	1.12	1.14	1.18	1.10	.....	.....	1.07	.....
30	1.14	.....	1.16	2.00	1.12	.....	.....	1.09	.....
31	1.16	.....	1.16	.....	1.18	.....	.....	1.09	.....

Mean daily discharge, in second-feet, of Frenchman River at Wauneta, 1896.

Day.	Aug.	Sept.	Day.	Aug.	Sept.	Day.	Aug.	Sept.	Day.	Aug.	Sept.
1	.....	86	9	.....	86	17	68	73	25	88	70
2	.....	86	10	.....	88	18	88	71	26	88	73
3	.....	84	11	.....	88	19	73	73	27	86	.....
4	.....	84	12	.....	68	20	68	73	28	86	.....
5	.....	84	13	.....	71	21	88	71	29	84	.....
6	.....	86	14	.....	71	22	88	71	30	88	.....
7	.....	86	15	.....	73	23	86	71	31	88	.....
8	.....	84	16	68	73	24	86	71			

FRENCHMAN RIVER AT PALISADE.

A station established just above the Burlington and Missouri River Railroad bridge at Palisade, October 14, 1894, was maintained until September 28, 1896.

The bed of the stream at this point is composed of loose, shifting sand, and reliable estimates of daily discharge can not be made without considerable expense.

Discharge measurements were made from the railroad bridge or by wading.

The gage was an inclined staff on the right bank immediately above the railroad bridge. The bench mark was the top of the second thread on the bottom of the east side of the north pile of the second bent from the right end of the bridge; elevation, 7.89 feet above the zero of the gage.

During the season of 1896 special effort was made to obtain sufficient data to afford reliable estimates of the daily discharge. Two supplementary gages were installed and the observer was instructed to make frequent soundings. The upstream gage was 325 feet above the main gage and the downstream gage 300 feet below the main gage. It was thus possible to obtain slopes of the water surface at the time of making soundings and current-meter measurements, and the resulting estimates are fairly reliable. The fall of the water table so obtained in a distance of 625 feet is shown in a table following. The gage heights are those observed on the main gage.

Heights on supplementary gages, Frenchman River at Palisade, 1896.

[Referred to original zero of main gage.]

Day.	Downstream gage.	Upstream gage.	Difference.	Day.	Downstream gage.	Upstream gage.	Difference.	Day.	Downstream gage.	Upstream gage.	Difference.
June 18	1.85	1.11	0.74	July 16	1.99	1.21	0.78	Aug. 25	1.87	1.08	0.79
June 23	2.11	1.35	.76	July 18	1.91	1.13	.78	Aug. 28	1.87	1.06	.81
June 25	2.10	1.35	.75	July 21	1.89	1.11	.78	Aug. 31	1.87	1.09	.78
June 27	2.06	1.34	.72	July 23	1.89	1.13	.76	Sept. 4	1.83	1.17	.66
July 1	2.14	1.40	.74	July 25	1.87	1.12	.75	Sept. 9	1.89	1.13	.76
July 3	2.13	1.39	.74	July 28	1.89	1.13	.76	Sept. 12	1.84	1.10	.74
July 5	2.13	1.38	.74	July 30	1.89	1.15	.74	Sept. 14	1.99	1.17	.82
July 7	2.03	1.27	.76	Aug. 1	1.89	1.14	.75	Sept. 20	1.98	1.19	.79
July 9	1.97	1.15	.82	Aug. 4	1.89	1.13	.76	Sept. 29	2.00	1.23	.77
July 11	1.94	1.17	.77	Aug. 6	1.89	1.13	.76				
July 14	1.96	1.19	.77	Aug. 8	1.88	1.12	.76				

Discharge measurements of Frenchman River at Palisade, 1894–1896.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
1894.		*Feet.*	*Sec.-ft.*	1896.		*Feet.*	*Sec.-ft.*
December 8	O. V. P. Stout	1.87	116	May 15	C. E. Crownover	1.55	103
1895.				June 18	O. V. P. Stout	1.35	50
March 22	do	1.52	100	July 15	E. T. Youngfeldt	1.46	93
June 5	do	1.76	154	August 13	O. V. P. Stout	1.36	64
July 4	do	1.61	74	September 16	E. T. Youngfeldt	1.51	85
August 9	do	1.50	68	October 17	C. E. Crownover	1.50	82
August 10	do	1.50	72				

Mean daily gage height, in feet, of Frenchman River at Palisade, 1894–1896.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1894.				1894.				1894.			
1		1.86	1.78	12		1.82	1.84	23	1.81	1.84	1.73
2		1.85	1.80	13		1.80	1.85	24	1.84	1.85	1.73
3		1.84	1.82	14	1.82	1.82	2.28	25	1.85	1.81	1.72
4		1.85	1.84	15	1.83	1.81	1.90	26	1.85	1.80	2.22
5		1.85	1.81	16	1.85	1.85	1.88	27	1.86	1.81	2.18
6		1.83	1.80	17	1.84	1.81	1.80	28	1.90	1.81	1.89
7		1.82	1.81	18	1.85	1.83	1.77	29	1.89	1.83	2.13
8		1.83	1.83	19	1.82	1.85	1.79	30	1.89	1.85	2.20
9		1.83	1.83	20	1.81	1.81	1.72	31	1.88	.....	2.25
10		1.81	1.84	21	1.80	1.83	1.71				
11		1.81	1.83	22	1.82	1.83	1.75				

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1895.											
1	2.31	2.50	1.60	1.55	1.63	1.75	1.65	1.55	1.49	1.60	.....
2	2.35	2.58	1.58	1.59	1.72	1.90	1.65	1.58	1.49	.....	1.64
3	2.38	2.58	1.55	1.58	1.63	1.80	1.63	1.63	1.50	.....	.....
4	2.40	2.59	1.60	1.59	1.66	1.70	1.61	1.60	1.51	.....	.....
5	2.42	2.60	1.60	1.60	1.66	1.72	1.60	1.55	1.52	1.61	1.60
6	2.36	2.55	1.60	1.70	1.73	1.75	1.60	1.55	1.50	.....	.....
7	2.38	2.50	1.55	1.75	1.70	1.73	1.81	1.55	1.50	.....	.....
8	2.40	2.45	1.52	1.75	1.68	1.68	1.75	1.53	1.50	1.62	.....
9	2.42	2.50	1.53	1.77	1.67	1.68	1.57	1.55	1.50	.....	1.60
10	2.45	2.62	1.53	1.75	1.65	1.70	1.60	1.50	1.50	.....	.....
11	2.45	2.72	1.55	1.74	1.65	1.93	1.65	1.51	1.51	.....	.....
12	2.46	2.82	1.53	1.73	1.66	1.72	1.65	1.50	1.50	1.62	1.60
13	2.42	2.83	1.54	1.74	1.66	1.68	1.65	2.05	1.49	.....	.....
14	2.48	2.84	2.00	1.73	1.66	1.67	2.69	1.90	1.50	.....	.....
15	2.48	2.85	1.90	1.72	1.64	1.67	1.95	1.55	1.50	1.62	.....

Mean daily gage height, in feet, of Frenchman River at Palisade, 1894–1896—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1895.											
16	2.48	2.89	1.94	1.72	1.63	1.68	1.85	1.55	1.50	.....	1.60
17	2.50	2.90	1.72	1.71	1.64	1.70	1.75	1.55	1.51	.....	.....
18	2.50	2.90	1.60	1.72	1.64	1.68	1.70	1.54	1.53	.....	.....
19	2.48	2.90	1.56	1.72	1.65	1.67	1.66	1.52	1.52	1.63	1.60
20	2.45	2.90	1.56	1.74	1.68	1.65	1.63	1.52	1.53	.....	.....
21	2.33	2.95	1.55	1.75	1.66	1.68	1.64	1.47	1.55	.....	.....
22	2.26	2.95	1.55	1.77	1.64	1.66	2.56	1.48	1.56	1.65	.....
23	2.20	2.94	1.52	1.70	1.64	1.65	2.45	1.50	1.57	.....	2.00
24	1.93	2.92	1.52	1.68	1.64	1.63	1.87	1.50	1.58	.....	.....
25	1.98	2.75	1.51	1.70	1.66	1.64	1.80	1.50	1.57	.....	.....
26	1.90	2.68	1.50	1.68	1.60	1.60	1.72	1.51	1.57	1.68	2.20
27	2.08	1.58	1.52	1.62	1.60	1.57	1.70	1.50	1.55	.....	.....
28	2.30	1.58	1.52	1.62	1.62	1.62	1.55	1.65	1.50	1.56	.....
29	2.28	.....	1.53	1.60	1.57	1.59	1.61	1.49	1.58	1.66	.....
30	2.35	.....	1.52	1.66	1.62	1.63	1.60	1.50	1.59	.....	1.90
31	2.43	.....	1.53	1.78	.....	.....	1.57	1.50	.....	.....	.....
1896.											
1	.....	.....	.....	1.63	1.86	1.55	1.70	1.42	1.48	1.48	1.65
2	.....	.....	.....	1.63	1.75	1.54	1.70	1.41	1.46	1.50	1.58
3	.....	.....	.....	1.63	1.75	1.54	1.68	1.40	1.46	1.52	1.58
4	.....	.....	.....	1.64	1.73	1.55	1.69	1.40	1.50	1.54	1.56
5	.....	.....	.....	1.64	1.75	1.53	1.67	1.40	1.45	1.54	1.56
6	.....	.....	.....	1.65	1.69	1.53	1.64	1.39	1.48	1.53	1.58
7	.....	.....	.....	1.64	1.67	1.51	1.60	1.40	1.50	1.50	1.60
8	.....	.....	.....	1.64	1.64	1.50	1.52	1.39	1.45	1.48	1.65
9	.....	.....	.....	1.65	1.64	1.50	1.46	1.39	1.45	1.48	1.65
10	.....	.....	.....	1.66	1.64	1.50	1.44	1.38	1.48	1.45	1.63
11	.....	.....	.....	1.65	1.65	1.49	1.43	1.37	1.48	1.45	1.65
12	.....	.....	.....	1.65	1.58	1.48	1.43	1.36	1.45	1.48	1.63
13	.....	.....	.....	1.61	1.55	1.48	1.44	1.36	1.50	1.48	1.60
14	.....	.....	.....	1.63	1.55	1.46	1.45	1.35	1.50	1.45	1.60
15	.....	.....	.....	1.63	1.54	1.44	1.46	1.36	1.50	1.48	1.60
16	.....	.....	.....	1.62	1.65	1.42	1.80	1.36	1.48	1.50	1.58
17	.....	.....	.....	1.73	1.63	1.41	1.47	1.50	1.50	1.50	1.58
18	.....	.....	.....	1.69	1.64	1.34	1.46	1.48	1.50	1.50	1.68
19	.....	.....	.....	1.65	1.62	1.35	1.45	1.46	1.48	1.53	1.63
20	.....	.....	.....	1.67	1.60	1.36	1.45	1.48	1.48	1.52	1.65
21	.....	.....	.....	1.66	1.56	1.48	1.44	1.51	1.48	1.52	1.65
22	.....	.....	.....	1.67	1.58	1.44	1.43	1.56	1.50	1.50	1.65
23	.....	.....	.....	1.67	1.61	1.80	1.44	1.50	1.48	1.50	1.65
24	.....	.....	.....	1.63	1.60	1.62	1.45	1.48	1.50	1.50	1.63
25	.....	.....	.....	1.64	1.58	1.67	1.45	1.50	1.50	1.48	1.63
26	.....	.....	.....	1.64	1.58	1.68	1.46	1.50	1.54	1.48	1.63
27	.....	.....	.....	1.65	1.58	1.66	1.47	1.48	1.50	1.45	1.60
28	.....	.....	.....	1.65	1.58	1.55	1.46	1.45	1.50	1.45	1.65
29	.....	.....	.....	1.68	1.58	1.56	1.45	1.42	1.50	1.48	.....
30	.....	.....	.....	1.70	1.55	3.00	1.44	1.48	1.48	1.65	.....
31	.....	.....	.....	.....	1.65	.....	1.42	1.45	.....	1.64	.....

Mean daily discharge, in second-feet, of Frenchman River at Palisade, 1894–1896.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1894.				1894.				1894.			
1	.....	113	91	11	.....	99	104	21	96	104	83
2	.....	110	96	12	.....	102	107	22	102	104	83
3	.....	107	102	13	.....	96	110	23	99	107	78
4	.....	110	107	14	102	102	110	24	107	110	78
5	.....	110	99	15	104	99	125	25	110	99	75
6	.....	104	96	16	110	110	118	26	110	96	.....
7	.....	102	99	17	107	99	96	27	113	99	.....
8	.....	104	104	18	110	104	88	28	125	96	.....
9	.....	104	104	19	102	110	93	29	122	122	.....
10	.....	99	107	20	99	99	75	30	122	110	.....
								31	118	.....	.....

Mean daily discharge, in second-feet, of Frenchman River at Palisade, 1894–1896—Cont'd.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1895.								
1	118	107	123	600	94	85	68	101
2	112	105	144	215	94	95	68	.....
3	107	112	123	171	84	130	71	.....
4	118	115	130	130	74	101	74	.....
5	118	118	130	138	69	85	77	104
6	118	140	146	150	69	85	71	.....
7	107	150	140	142	79	85	71	.....
8	100	150	134	122	142	79	71	107
9	102	156	132	122	54	85	71	.....
10	102	150	128	130	69	71	71	.....
11	107	147	128	229	94	74	74	.....
12	102	146	130	128	94	74	71	107
13	104	147	130	109	84	437	68	.....
14	104	146	130	104	580	216	71	.....
15	104	144	125	104	239	85	71	107
16	104	144	123	109	195	85	71	.....
17	104	142	125	118	154	85	74	.....
18	104	144	125	109	135	82	79	.....
19	109	146	128	104	121	77	77	111
20	109	147	134	94	111	77	79	.....
21	107	150	130	109	113	64	85	.....
22	102	156	125	99	580	66	88	117
23	100	140	125	94	513	71	91	.....
24	100	134	125	84	203	71	95	.....
25	99	140	130	89	174	71	91	.....
26	98	134	118	69	143	74	91	128
27	100	122	118	58	135	71	85	.....
28	100	122	137	50	117	71	88	.....
29	102	118	111	65	104	68	95	121
30	100	130	111	84	101	71	98	.....
31	102	.....	158	.....	91	71	.....	.....

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Day.	May.	June.	July.	Aug.	Sept.	Oct.
1896.							1896.						
1	200	92	110	79	81	81	17	112	60	93	83	83	83
2	140	89	110	76	78	83	18	113	50	90	81	83	83
3	140	89	109	75	78	86	19	110	51	89	78	81	87
4	130	89	112	75	83	89	20	107	53	89	81	81	86
5	140	86	109	74	86	89	21	100	71	86	85	81	89
6	120	85	107	72	81	87	22	103	66	85	92	83	83
7	120	82	103	74	83	83	23	105	116	86	83	81	83
8	116	79	92	71	76	81	24	104	93	86	81	83	83
9	116	79	85	71	76	81	25	100	101	86	83	83	81
10	116	78	83	69	81	76	26	100	103	87	83	89	81
11	118	76	83	66	81	76	27	98	93	87	81	83	76
12	108	74	85	64	76	81	28	98	87	86	76	83	76
13	104	74	87	64	83	81	29	97	89	85	72	83	81
14	104	69	90	62	83	76	30	92	800	82	81	81	.....
15	103	65	92	64	83	81	31	105	.....	79	76	.....	.....
16	116	61	105	64	81	83							

Estimated monthly discharge of Frenchman River at Palisade, 1894–1896.

[Drainage area, 1,030 square miles.]

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
1894.								
October 14-31	125	97	109	3,890	.....	.....	.....	0.30
November	122	97	73	6,250	0.101	0.11	100	.11
December	125	73	97	5,960	.094	.11	73	.15
1895.								
March	118	98	105	6,460	.102	.12	27	.45
April	156	107	137	8,150	.133	.15	12	1.20
May	158	111	129	7,930	.125	.14	7	2.09
June	600	50	132	7,850	.128	.14	3	4.24
July	580	54	158	9,720	.153	.18	5	3.96
August	437	64	96	5,900	.092	.11	3	3.95
September	98	68	78	4,640	.076	.08	6	1.40
October	128	101	111	6,820	.108	.12	80	.15
1896.								
May	200	92	114	7,010	.111	.13	5	2.77
June	800	50	104	6,190	.100	.11	4	3.08
July	145	80	94	5,780	.091	.10	10	1.00
August	92	63	76	4,670	.073	.08	3	2.67
September	89	76	82	4,880	.079	.09	5	1.95
October	89	76	82	5,040	.079	.09	5	1.80

MISCELLANEOUS MEASUREMENTS IN KANSAS RIVER BASIN.

The following discharge measurements have been made in the basin of Kansas River at points other than the regular gaging stations in Nebraska:

Miscellaneous discharge measurements in Kansas River drainage basin, 1895–1904.

Stream.	Locality.	Date.	Hydrographer.	Discharge.
				Sec.-feet.
Beaver Creek	Geneva	July 23, 1901	O. V. P. Stout	75
Do	do	Aug. 30, 1901	do	86
Blue River, Big	Beatrice	Aug. 21, 1897	do	20.3
Do	do	July 4, 1898	do	285
Do	Seward [a]	July 1, 1898	do	42.7
Do	do	Apr. 5, 1902	J. C. Stevens	50
Do	Milford [b]	July 1, 1898	O. V. P. Stout	53.4
Do	Crete [b]	July 2, 1898	do	127
Do	do	Apr. 18, 1902	J. C. Stevens	143
Do	do	do	do	132
Do	do	May 30, 1903	do	[c] 13,380
Do	De Witt [d]	July 2, 1898	O. V. P. Stout	202
Do	De Witt	June 7, 1900	do	235
Do	do	May 30, 1903	J. C. Stevens	11,300
Do	Blue Springs	June 7, 1900	O. V. P. Stout	262
Do	Wilbur	do	do	190
Do	Wymore	July 12, 1901	do	235
Do	do	Sept. 16, 1902	J. C. Stevens	234
Do	do	Sept. 11, 1903	do	567
Do	do	June 4, 1904	do	664
Do	do	June 28, 1904	do	453
Do	Oak	July 14, 1904	J. A. Green	517
Blue River, Little	Ayr	Aug. 23, 1900	J. C. Stevens	1.7
Do	W. line sec. 18, T. 5 N., R. 10 W.	do	do	1.6
Buffalo Creek	Moore's ranch	June 17, 1896	E. T. Youngfelt	7.9
Do	Sec. 7, T. 1 N., R. 40 W	Nov. 22, 1900	W. A. Channel	9.9
Center Creek	Sec. 36, T. 2 N., R. 15 W	June 10, 1902	H. O. Smith	7.6
Do	Sec. 7, T. 1 N., R. 5 W	do	do	7.7

[a] Below dam, mill not running. [b] Below mill. [c] Flood. [d] 1,000 feet below mill.

Miscellaneous discharge measurements in Kansas River drainage basin, 1895–1904—Con.

Stream.	Locality.	Date.	Hydrographer.	Discharge.
				Sec.-feet.
Cook Creek	Sec. 2, T. 2 N., R. 18 W	Sept. 24, 1901	H. O. Smith	0.9
Crooked Creek	Sec. 1, T. 1 N., R 11 W	July 2, 1902	B. E. Forbes	[a] 175
Culbertson canal	Sec. 31, T. 5 N., R. 33 W	June 19, 1896	O. V. P. Stout	61
Dundy County Irrigation ditch.	Sec. 24, T. 1 N., R. 39 W	June 16, 1896	do	6.2
Flag Creek	Sec. 3, T. 2 N., R. 19 W. [b]	Sept 24, 1901	H. O. Smith	1.5
Do	Sec. 3, T. 3 N., R. 19 W. [c]	do	do	.6
Do	Sec. 15, T. 2 N., R. 19 W. [d]	do	do	.5
Flowing well	Sec. 13, T. 6 N., R. 40 W	July 24, 1901	do	.5
Frenchman River	Culbertson	Nov. 25, 1892		177
Do	do	Mar. 22, 1895	O. V. P. Stout	120
Do	do	June 19, 1896	E. T. Youngfelt	13.4
Do	do	Sept. 16, 1899	A. B. McCoskey	29.7
Do	do	Aug. 17, 1900	O. V. P. Stout	84
Do	do	July 23, 1901	H. O. Smith	62
Do	do	Apr. 25, 1902	F. Dobson	92
Do	do	Sept. 18, 1902	J. C. Stevens	66
Do	do	Aug. 5, 1903	H. O. Smith	71
Do	do	Aug. 29, 1903	do	57
Do	Wauneta	Apr. 14, 1897	Adna Dobson	128
Do	do	Sept. 19, 1899	A. B. McCoskey	63
Do	do	July 27, 1900	do	74
Do	do	June 21, 1901	H. O. Smith	113
Do	Palisade	July 2, 1897	O. V. P. Stout	63
Do	do	July 19, 1897	do	73
Do	do	July 7, 1898	Glenn E. Smith	92
Do	do	do	do	33
Do	do	May 29, 1899	H. H. Pickens	97
Do	do	Sept. 16, 1899	A. B. McCoskey	66
Do	do	July 27, 1900	do	91
Do	do	June 21, 1901	H. O. Smith	176
Do	do	June 30, 1904	J. A. Green	240
Do	Maranville	July 8, 1899	E. D. Johnson	19
Do	Enders	June 13, 1902	H. O. Smith	60
Do	Champion	June 29, 1904	J. A. Green	45
Do	Head of Krotter ditch	Aug. 5, 1903	H. O. Smith	66
Do	Sec. 33, T. 4 N., R. 32 W	June 19, 1896	O. V. P. Stout	26.3
Do	Sec. 17, T. 6 N., R. 40 W. [e]	July 9, 1899	E. D. Johnson	16.6
Do	Sec. 24, T. 6 N., R. 40 W. [f]	July 10, 1899	do	21
Do	Sec. 17, T. 6 N., R. 40 W. [g]	July 26, 1900	A. B. McCoskey	[h] 3.4
Do	Sec. 12, T. 6 N., R. 41 W. [i]	do	do	[h] 8
Do	do. [i]	Sept. 29, 1900	E. D. Johnson	6.2
Do	Sec. 24, T. 6 N., R. 40 W	May 31, 1901	H. O. Smith	11.6
Do	do. [j]	July 26, 1900	A. B. McCoskey	[h] 14
Do	do	June 18, 1901	H. O. Smith	14.8
Do	Sec. 17, T. 6 N., R. 40 W	May 31, 1901	do	10.6
Do	do	June 18, 1901	do	18
Do	Sec. 18, T. 3 N., R. 31 W	July 26, 1900	Adna Dobson	79
Do	do	July 29, 1900	do	79
Do	W. line sec. 3, T. 5 N., R. 38 W.	June 3, 1899	H. H. Pickens	29.5
Do	Sec. 21, T. 6 N., R. 39 W	June 18, 1901	H. O. Smith	47.3
Do	Sec. 5, T. 5 N., R. 36 W	June 21, 1901	do	93
Do	Sec 18, T. 16 N., R. 49 W	June 28, 1904	J. A. Green	10
Graff ditch	Near head	July 26, 1900	E. D. Johnson	13.3
Horse Creek	Sec. 23, T. 1 N., R. 39 W. [k]	June 16, 1896	E. T. Youngfelt	.2
Do	Sec. 11, T. 1 N., R. 39 W	Nov. 22, 1900	W. A. Channel	1.2
Indian Creek	Sec. 26, T. 2 N., R. 36 W. [l]	June 25, 1896	E. T. Youngfelt	.1
Do	Line bet. secs. 10, 11, T. 2 N., R. 37 W.	Nov. 14, 1900	W A Channel	1.3
Lost Creek	Sec. 10, T. 1 N., R. 15 W	June 10, 1902	H. O. Smith	.7
Medicine Creek	Cambridge	June 28, 1900	Adna Dobson	24.5
Do	Curtis	July 11, 1904	J. A. Green	66
Methodist Creek	Sec. 2, T. 1 N., R. 18 W	Sept. 24, 1901	H. O. Smith	2.6
Mill race	Naponee	July 7, 1904	J. A. Green	24
Muddy Creek	Sec. 8, T. 4 N., R. 23 W	June 28, 1900	Adna Dobson	3.7
Neighbor ditch	Sec. 24, T. 1 N., R. 39 W	June 16, 1896	O. V. P. Stout	1.1
Naponee	Naponee	do	do	19
Porter's ditch	Haigler	June 17, 1896	do	9
Republican River	Culbertson	Nov. 25, 1892	U. S. G. S	209
Do	do	May 16, 1896	C. E. Crownover	78
Do	do	June 19, 1896	O. V. P. Stout	6.5
Do	do	Sept. 10, 1896	do	0
Do	do	June 25, 1898	do	91
Do	do	May 29, 1899	do	0
Do	do	Sept. 19, 1899	A. B. McCoskey	0

[a] Flood.
[b] Above dam.
[c] Below dam.
[d] Two miles below dam.
[e] Below head of Inman ditch.
[f] Below head of Wirsig ditch.
[g] Head of Maranville ditch.
[h] Ditch diverting all water.
[i] Head of Inman ditch.
[j] Head of Wirsig ditch.
[k] At Burlington and Missouri Railway crossing.
[l] Near mouth.

Miscellaneous discharge measurements in Kansas River drainage basin, 1895–1904—Con.

Stream.	Locality.	Date.	Hydrographer.	Discharge.
				Sec.-feet.
Republican River	Culbertson	Sept. 29, 1900	O. V. P. Stout	0
Do	do	July 20, 1901	do	0
Do	do	Sept. 18, 1902	J. C. Stevens	41
Do	do	Apr. 25, 1902	F. Dobson	204
Do	do	Aug. 29, 1903	H. O. Smith	0
Do	Oxford	June 3, 1895	O. V. P. Stout	[a] 16,000
Do	do	Sept. 12, 1895	do	55
Do	do	May 17, 1896	C. E. Crownover	255
Do	do	June 20, 1896	O. V. P. Stout	109
Do	do	June 24, 1898	do	385
Do	do	Sept. 6, 1899	Glenn E. Smith	0
Do	do	July 18, 1900	E. D. Johnson	14.3
Do	do	July 22, 1901	H. O. Smith	0
Do	do	Sept. 17, 1902	J. C. Stevens	37
Do	do	Apr. 27, 1902	F. Dobson	255
Do	do	May 19, 1903	J. C. Stevens	556
Do	Sec. 24, T. 1 N., R. 39 W	June 20, 1896	O. V. P. Stout	88
Do	Sec. 19, T. 1 N., R. 39 W	Aug. 25, 1896	do	5
Do	Sec. 22, T. 3 N., R. 31 W	June 22, 1901	H. O. Smith	0
Do	Benkelman	June 16, 1896	O. V. P. Stout	29.3
Do	do	Aug. 25, 1896	do	0
Do	do	Aug. 18, 1900	do	41.7
Do	do	June 12, 1902	H. O. Smith	35
Do	do	Sept. 17, 1902	J. C. Stevens	45
Do	McCook	Apr. 13, 1897	Adna Dobson	745
Do	do	July 19, 1897	O. V. P. Stout	0
Do	do	Sept. 19, 1899	A. B. McCoskey	12.3
Do	do	July 27, 1900	do	104
Do	do	July 20, 1901	O. V. P. Stout	0
Do	do	Sept. 17, 1902	J. C. Stevens	29
Do	do	Apr. 27, 1902	F. Dobson	137
Do	do	July 1, 1904	J. A. Green	443
Do	Orleans	Sept. 6, 1899	A. B. McCoskey	.3
Do	Head of Meeker canal	Sept. 19, 1899	E. D. Johnson	17.5
Do	Cambridge	June 28, 1900	Adna Dobson	72
Do	Edison	July 18, 1900	E. D. Johnson	16.6
Do	Ives	Apr. 26, 1902	F. Dobson	39
Do	Stratton	do	do	85
Do	Franklin	June 10, 1902	H. O. Smith	743
Do	Wray (Colo.)	May 21, 1903	J. C. Stevens	34.7
Do	Warwick (Kans.)	June 5, 1904	do	741
Do	Naponee	July 7, 1904	J. A. Green	1,264
Do	Haigler[b]	Oct. 16, 1896	E. T. Youngfelt	6
Do	do.[c]	June 17, 1896	O. V. P. Stout	8.2
Do	do	do	do	23.9
Do	do	do	E. T. Youngfelt	14.9
Do	do	July 16, 1896	O. V. P. Stout	9.8
Do	do	do	E. T. Youngfelt	6.2
Do	do	Aug. 25, 1896	O. V. P. Stout	10
Do	do	Sept. 18, 1896	do	24.5
Do	do	Apr. 26, 1902	F. Dobson	52
Do	do	May 21, 1903	J. C. Stevens	16
Republican River, Arickaree Fork.	do	June 17, 1896	O. V. P. Stout	15.1
Do	do	July 16, 1896	do	3.6
Republican River, South Fork.	Benkelman	June 16, 1896	E. T. Youngfelt	3.2
Do	3,000 feet west of, above	do	do	1.4
Do	Benkelman	Aug. 18, 1900	O. V. P. Stout	3
Do	Kans.-Nebr. state line	June 12, 1902	H. O. Smith	32.8
Rock Creek	Ives[d]	June 16, 1896	O. V. P. Stout	12.1
Do	do	Aug. 25, 1896	E. T. Youngfelt	12.2
Do	do	Apr. 26, 1902	F. Dobson	9.9
Do	Sec 21, T. 1 N., R. 39 W	Nov. 22, 1900	W. A. Channel	8.8
Sappa Creek	Stamford	July 6, 1904	J. A. Green	36
Stinking Water	Palisade[e]	June 19, 1896	O. V. P. Stout	12.2
Do	do[f]	Sept. 17, 1896	E. T. Youngfelt	20
Do	Palisade	July 7, 1898	Glenn E. Smith	23.6
Do	do	June 30, 1904	J. A. Green	79
Do	do	do	do	63
Thompson Creek	Sec. 4, T. 2 N., R. 13 W	Sept. 8, 1899	E. D. Johnson	3.4
Turkey Creek	Sec. 30, T. 4 N., R. 21 W	Sept. 6, 1899	do	2.3
Do	Naponee	Aug. 24, 1900	O. V. P. Stout	7
Do	do	July 7, 1904	J. A. Green	.9
—— (No name)	Sec. 25, T. 2 N., R. 19 W	Sept. 24, 1901	H. O. Smith	1.4
Do	Sec. 31, T. 2 N., R. 18 W	do	do	.3
Do	Sec. 32, T. 2 N., R. 18 W	do	do	.6

[a] Flood.
[b] Above mouth of Arickaree.
[c] Below mouth of Arickaree.
[d] Burlington and Missouri Railway crossing.
[e] Above Palisade mill.
[f] Below Palisade mill.

PRECIPITATION IN THE REPUBLICAN BASIN.

The following is a list of the precipitation stations in the Republican basin:

Rainfall stations in Republican River basin.

Station.	County.	Latitude.	Longitude.	Elevation.	Length of record.
		° ′	° ′	*Feet.*	*Years.*
Superior	Nuckolls	40 02	98 02	1,570	22
Red Cloud	Webster	40 05	98 37	1,687	15
Franklin	Franklin	40 06	98 56	1,817	18
Republican	Harlan	40 04	99 15	1,939	12
Minden	Kearney	40 29	98 57	2,162	29
Holdrege	Phelps	40 26	99 22	2,324	16
Norton (Kans.)	Norton	39 50	99 51	2,284	4
Beaver City	Furnas	40 08	99 50	2,147	15
Wilsonville	do	40 06	100 07	2,298	12
Oberlin (Kans.)	Decatur	39 49	100 34	2,539	14
Curtis	Frontier	40 38	100 32	2,553	11
Culbertson	Hitchcock	40 12	100 48	2,565	19
Stratton	do	40 09	101 13	2,793	11
Hayes Center	Hayes	40 31	101 01	.....	13
Imperial	Chase	40 32	101 38	3,278	16
Wallace	Lincoln	40 51	101 10	3,116	16
Madrid [a]	Perkins	40 52	101 33	3,405	14
Benkelman	Dundy	40 03	101 32	2,968	12
Haigler	do	40 01	101 56	3,256	14
Wray (Colo.)	Yuma	40 06	102 13	3,512	13
Yuma (Colo.)	do	40 07	102 44	4,138	16
Leroy (Colo.)	Logan	40 32	103 00	4,380	18

[a] Now Grant, for which place latitude, longitude, and elevation are given.

The subjoined table shows the precipitation at the stations named in the foregoing list:

Precipitation at stations in drainage basin of Republican River, 1896–1906.

SUPERIOR, NUCKOLLS COUNTY.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.56	0.77	1.10	3.08	3.94	4.23	4.93	2.75	2.31	2.16	0.78	0.55	27.16
1896	.42	.14	1.80	5.86	9.09	2.72	5.05	6.46	4.88	3.98	1.43	.00	41.83
1897	.35	.25	1.30	5.64	1.71	8.39	3.90	1.39	2.08	4.87	.75	1.00	31.63
1898	1.00	.80	.55	2.70	4.96	3.79	1.15	.87	4.00	.80	.80	.60	22.02
1899	.00	1.60	1.00	1.55	3.10	5.61	5.20	2.05	T.	3.90	.62	1.15	25.78
1900	T.	1.35	.60	7.60	2.20	3.75	2.20	2.70	2.90	2.50	.20	.45	26.45
1901	1.00	.80	1.75	2.95	.75	2.10	2.20	1.35	1.95	1.45	.18	.16	16.64
1902	.90	.80	.62	.15	4.61	8.69	10.45	5.14	4.52	3.52	.68	.80	40.88
1903	.20	1.40	.20	1.70	13.11	2.25	7.56	2.17	.60	3.87	1.49	T.	34.55
1904	.15	T.	1.39	2.62	2.10	6.46	5.52	2.13	1.75	1.20	T.	.20	23.52
1905	1.20	1.10	.88	3.62	3.34	4.10	5.98	1.94	1.27	.30	1.95	.05	26.54
1906	.40	.31	1.87	4.44	3.30	2.52	1.66	2.07	2.52	2.46	.05	.68	22.28

RED CLOUD, WEBSTER COUNTY.

Normal	0.33	0.59	0.77	2.27	3.32	4.75	4.30	2.73	2.77	1.81	0.59	0.51	24.74
1896	.57	.10	1.55	6.63	5.60	2.67	2.44	5.60	2.60	2.50	1.80	.00	32.06
1897	.40	.36	.93	4.97	1.63	10.93	4.32	1.06	1.44	5.21	.60	1.00	32.85
1898	.45	.15	.25	3.20	3.25	1.30	1.63	.28	4.75	.84	.93	.73	17.76
1899	.04	.90	.95	.63	2.57	7.05	5.01	2.29	.09	1.88	1.04	1.17	23.62
1900	T.	.70	1.03	4.45	2.22	.61	2.98	1.34	3.92	1.86	.30	.48	19.89
1901	.49	.90	2.48	2.14	1.25	4.41	2.30	3.68	4.28	1.60	.09	.15	23.77
1902	.50	.70	.89	.71	3.80	7.75	13.52	1.99	5.75	2.91	.72	.67	39.91
1903	.30	1.32	.33	1.85	10.85	2.16	2.80	6.76	.28	2.67	1.18	T.	30.50
1904	.07	.10	.85	2.71	2.83	4.21	6.30	3.45	2.30	1.76	.05	.15	24.78
1905	.....	.65	.....	4.03	5.33	5.34	7.91	2.08	2.96	.12	2.20	.....	.....
1906	.85	.51	.....	4.52	.....	1.50	4.42	.....	2.40	2.48	.50	.91	.....

Precipitation at stations in drainage basin of Republican River, 1896–1906—Continued.

FRANKLIN, FRANKLIN COUNTY.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.42	0.63	0.84	2.52	3.86	3.63	3.80	2.78	2.79	1.92	0.57	0.42	24.08
1896	.70	.00	.85	6.87	4.28	.....	.....	.....	2.00	1.23	.70	.00	.....
1897	.60	.55	.61	.....	1.13	5.50	2.45	3.53	2.46	5.99	.44	1.40	.....
1898	.30	.30	.05	4.46	4.39	3.59	1.14	.30	4.12	2.10	.....	.....	.....
1899	.00	.75	.90	1.25	5.96	5.61	3.70	2.65	.....	.....	.....	.....	.....
1900	.00	1.42	.39	5.57	2.83	1.84	1.95	1.62	5.08	2.14	.60	.....	.....
1901	.40	1.00	1.58	2.76	1.56	1.02	2.12	2.01	4.70	1.15	.45	.....	.....
1902	.60	.....	1.15	.20	3.92	6.95	6.21	.....	7.40	3.06	T.	.85	.....
1903	.20	1.50	.....	2.57	9.98	1.25	3.59	5.17	.20	2.13	1.13	.00	.....
1904	.10	.15	.35	2.57	4.43	.....	.....	.....	.....	3.17	.02	.02	.....
1905	1.00	.65	.20	3.27	3.83	4.88	9.41	1.78	2.46	.59	2.70	.00	30.77
1906	.38	.53	2.30	3.87	.....	1.93	2.17	1.92	1.14	2.67	.10	.75	.....

REPUBLICAN, HARLAN COUNTY.

Normal	0.21	0.56	0.77	3.27	3.22	3.39	3.71	2.92	2.66	1.74	0.70	0.29	23.44
1896	.25	.00	1.04	7.17	2.75	2.25	5.70	3.68	1.50	1.04	1.45	T.	26.83
1897	.40	.60	.70	4.04	1.40	3.56	2.21	6.41	1.23	3.76	.30	.95	25.56
1898	.10	.25	.08	4.68	5.03	4.00	1.80	1.39	5.40	.....	.85	.05	.....
1899	.20	.30	.15	1.35	3.18	5.37	3.03	.70	.25	.30	1.58	.62	17.03
1900	.00	.77	.80	4.47	.45	1.65	2.80	.52	3.35	1.79	.30	.05	16.95
1901	.30	.30	1.76	3.81	.65	1.80	.20	2.91	6.74	1.45	.....	.10	.....
1902	.35	.52	1.40	.45	4.85	3.98	8.91	1.54	5.41	2.24	.....	.95	.....
1903	.25	2.00	.....	.....	.....	1.94	6.00	4.51	.62	1.20	.80	T.	.....
1904	.05	.02	.20	1.80	5.56	3.91	3.14	6.06	1.62	3.66	.00	.00	26.02
1905	.70	1.70	.35	3.20	5.10	9.60	4.32	3.70	.....	.45	.....	.00	.....
1906	.55	.29	1.80	.....	.....	.....	.40	5.50	2.00	3.10	.....	.50	.....

MINDEN, KEARNEY COUNTY.

Normal	0.84	1.08	1.45	3.60	5.12	5.07	4.76	3.59	2.74	2.07	0.90	0.67	31.29
1896	.75	.15	1.72	10.82	6.28	2.61	3.54	2.61	2.63	1.87	1.77	.09	34.84
1897	.80	1.25	1.93	4.48	2.11	4.99	3.05	2.27	1.04	7.34	.97	1.61	31.84
1898	.31	.44	.32	4.02	5.34	4.44	1.50	4.23	4.39	1.04	.87	.30	27.20
1899	.03	.98	1.11	1.23	2.83	9.61	3.39	2.89	.90	.45	1.15	1.00	25.57
1900	.05	1.67	1.35	3.96	4.09	1.84	1.92	2.89	4.16	3.41	.97	.77	27.08
1901	.34	1.68	2.51	3.61	.83	3.80	1.37	3.22	7.67	1.34	.79	.18	27.34
1902	.64	.56	1.77	.55	8.73	6.33	7.58	2.96	5.16	2.94	.12	.91	38.25
1903	.33	2.61	1.17	1.83	9.57	2.67	8.26	8.16	.73	1.77	.91	.01	38.02
1904	.06	.11	.47	1.87	2.55	6.43	4.10	2.74	1.48	4.64	.11	.20	24.67
1905	.99	1.06	.78	3.89	7.19	4.86	6.26	2.72	4.07	.57	2.36	.03	34.78
1906	.40	1.02	1.80	4.28	.78	2.40	3.35	2.91	1.74	2.95	.62	.92	23.17

HOLDREGE, PHELPS COUNTY.

Normal	0.40	0.86	1.14	3.58	5.01	3.98	3.38	2.78	2.40	1.84	0.60	0.52	26.49
1896	.00	T.	1.20	7.50	5.55	4.70	3.10	3.10	2.75	.70	1.35	T.	29.95
1897	.70	1.01	2.30	5.80	2.80	3.45	3.85	.95	2.30	4.35	.27	1.00	28.78
1898	.80	.25	.03	3.35	4.96	3.85	1.85	1.83	5.05	.73	.10	T.	22.80
1899	T.	.30	.20	T.	7.25	.....	3.60	.....	.70	.00	1.50	.95	.....
1900	T.	1.61	.....	5.84	2.74	1.94	3.85	2.62	2.40	3.30	.35	.20	.....
1901	.20	.70	4.25	6.01	.65	.85	.50	3.25	4.21	.75	.70	.30	22.37
1902	.50	.20	1.40	.75	10.08	7.18	4.68	2.85	.....	3.66	T.	1.20	.....
1903	.20	2.30	.....	1.83	12.36	2.48	7.15	4.90	.40	2.10	.....	T.	.....
1904	.18	.10	.07	1.93	3.90	.....	2.82	3.47	1.63	3.43	.10	.20	.....
1905	.80	1.70	.20	4.80	6.86	11.83	6.21	2.26	3.60	.10	1.85	.00	40.21
1906	.30	.70	1.85	7.90	1.40	.92	4.30	4.46	2.87	3.90	1.04	1.12	30.76

Precipitation at stations in drainage basin of Republican River, 1896–1906—Continued.

NORTON, NORTON COUNTY, KANS.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896	0.45	T.	0.10	1.61	0.70	1.64	0.90	0.22	2.01	0.75	0.24	0.68	9.30
1897	.80	1.55	.10	3.49	.....	.....	.....	.....	.....	.....	.....	.....	.....
1898	.19	.01	.16	3.62	5.60	.....	4.98	1.87	.....	.....	.....	.....	.....
1903	.....	.....	.....	.....	.....	.....	.....	4.45	.45	1.29	.25	T.	.....
1904	.02	T.	.50	3.02	3.41	5.11	3.92	2.61	1.45	3.65	.35	.35	24.39
1905	.85	1.23	.59	2.30	6.18	3.10	7.31	.41	1.90	.56	1.58	T.	26.01
1906	.45	.12	2.22	5.18	6.65	1.32	3.54	1.80	.50	3.27	.42	.....	.....

BEAVER CITY, FURNAS COUNTY.

Normal	0.26	0.63	0.80	2.71	3.13	4.03	4.33	2.34	2.03	1.27	0.62	0.43	22.58
1896	.56	.06	.56	4.98	2.68	5.83	3.28	2.54	2.15	.87	.33	.14	23.98
1897	.28	.38	1.30	5.30	.85	3.54	3.13	1.50	2.16	4.81	.39	1.09	24.73
1898	.18	.02	.16	2.27	3.69	3.73	1.60	2.23	5.51	.32	.58	.06	20.35
1899	.10	.32	.60	.50	1.28	2.86	3.94	1.45	.43	.02	2.07	.66	14.23
1900	T.	1.41	.62	4.87	1.01	2.26	2.12	.67	1.67	.62	.20	.28	15.73
1901	.20	.67	2.46	3.52	.77	.95	1.30	4.96	3.57	.89	.41	.11	19.81
1902	.60	.35	.49	.62	5.82	4.26	6.82	1.53	2.57	2.06	.04	.79	25.95
1903	.25	1.85	.93	2.16	11.05	1.85	6.29	3.39	.24	.90	.71	.01	29.63
1904	.01	.05	.27	2.02	3.53	4.04	.83	2.02	2.06	3.83	.10	.19	18.95
1905	.63	.67	.70	2.90	4.94	8.09	13.90	2.89	2.57	.79	1.42	.00	39.50
1906	.33	.66	1.28	5.51	.71	1.79	4.32	2.51	1.54	3.58	.80	1.19	24.22

WILSONVILLE, FURNAS COUNTY.

Normal	0.21	0.65	0.76	3.51	3.75	3.48	3.01	2.64	1.94	1.27	0.51	0.33	22.06
1896	.35	.05	.35	6.70	3.25	3.60	1.62	3.27	2.07	1.19	.27	.00	22.72
1897	.38	.45	.....	6.61	1.26	2.97	1.05	4.63	2.70	3.90	.55	1.30	.....
1898	.15	.15	T.	2.35	4.82	4.05	1.92	2.61	4.25	.35	.35	.00	21.00
1899	.30	.40	.40	.40	1.95	3.00	6.10	1.45	.00	.00	2.00	.50	16.50
1900	T.	1.00	.80	5.95	1.20	1.70	3.07	.70	1.26	.26	.05	T.	15.99
1901	.36	.70	3.87	3.35	.63	1.90	.76	3.44	3.92	.72	.66	.32	20.63
1902	.....	.....	.59	1.04	6.44	3.93	4.31	3.16	2.20	2.56	T.	.48	.....
1903	.20	2.10	.32	2.15	11.60	1.45	2.15	2.78	.68	.35	.60	T.	24.38
1904	T.	.20	.51	2.67	2.74	7.07	5.68	2.02	1.05	2.98	.08	.40	25.40
1905	.71	.95	1.22	3.75	5.56	3.36	8.22	1.75	.....	.....	.....	.00	.....
1906	.30	.20	2.10	5.10	1.75	3.00	2.20	.....	.....	2.65	.35	.....	.....

OBERLIN, DECATUR COUNTY, KANS.

Normal	0.46	0.97	0.87	2.71	3.62	2.64	3.76	3.00	1.98	2.22	0.64	0.63	23.80
1896	.40	.20	.90	6.01	4.47	5.36	2.82	2.88	1.60	1.75	.50	.10	25.49
1897	.40	1.10	3.30	6.70	.28	5.00	2.65	4.75	2.94	5.07	.50	1.80	34.49
1898	.48	.00	.40	2.18	5.03	3.43	5.30	1.35	5.61	1.70	1.00	.40	26.88
1899	.85	.40	.85	1.15	3.15	2.37	3.61	2.49	.26	.00	2.45	.25	17.83
1900	T.	1.60	1.00	4.50	1.10	1.73	2.58	1.70	1.93	.00	.10	.30	16.54
1901	.20	1.00	3.05	3.95	1.00	3.45	.37	5.31	5.37	.50	.25	.70	25.15
1902	.85	.65	1.60	1.35	4.89	3.43	5.43	2.25	1.60	2.36	.00	1.35	25.76
1903	.20	2.80	.70	1.30	6.45	1.46	3.75	2.55	.70	.47	.75	.00	21.13
1904	.00	.00	.25	4.10	4.49	5.54	2.36	5.85	2.05	2.41	.20	.65	27.90
1905	.95	.60	1.28	3.13	2.83	2.96	6.67	2.46	2.65	.80	.65	.00	24.98
1906	.60	.....	2.35	3.48	.70	2.14	1.71	2.90	1.73	3.40	.....	.....	.....

Precipitation at stations in drainage basin of Republican River, 1896–1906—Continued.

CURTIS, FRONTIER COUNTY.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.28	0.91	1.51	2.35	2.63	4.34	3.11	2.79	1.84	1.41	0.65	0.39	22.21
1896	.31	.12	2.20	5.85	2.55	5.03	3.89	2.71	1.67	3.00	.60	.52	28.45
1897	T.	.50	2.58	5.10	.43	4.08	.60	3.26	1.27	4.73	1.60	1.10	25.25
1898	.60	.20	.25	2.32	5.34	3.27	2.56	1.67	3.70	.33	.63	.16	21.03
1899	.....	.30	1.16	.26	2.72	3.24	5.70	2.55	.55	.15	2.65	.....	.....
1900	.00	2.40	1.65	3.13	.27	2.47	3.20	5.79	1.04	T.	.20	.....	.....
1901	.00	.80	4.27	2.64	1.11	5.37	.20	2.01	4.44	.60	.35	.20	21.99
1902	1.00	.60	2.00	1.05	4.81	2.98	4.65	2.35	2.80	2.45	.....	1.20	.....
1903	.30	2.60	.60	1.10	4.78	4.04	6.28	.....	.....	.....	.40	.10	.....
1904	.05	.10	.40	.83	3.38	6.53	3.48	4.32	1.69	2.41	T.	.28	23.47
1905	1.10	.60	1.15	3.78	5.73	8.95	7.26	1.75	4.52	1.48	.87	.00	37.19
1906	.45	.60	.....	.....	.....	.....	1.34	.....	.....	.....	.....	.....	.....

CULBERTSON, HITCHCOCK COUNTY.

Normal	0.38	0.61	1.11	2.46	2.75	3.47	3.02	2.67	1.54	1.17	0.39	0.37	19.94
1896	.56	.00	.57	4.38	2.77	3.08	.53	2.67	1.95	1.80	.10	T.	18.41
1897	.71	.77	1.90	4.73	.75	8.67	1.29	2.95	1.13	4.84	.38	.85	28.97
1898	.40	.00	.24	2.10	3.84	3.48	1.44	1.34	3.90	2.52	.37	.07	19.70
1899	.50	1.07	.94	.45	1.93	3.61	3.95	3.24	.03	.23	1.65	.11	17.71
1900	.02	1.72	.78	3.25	1.03	1.72	4.20	1.00	.70	.49	.15	.41	15.47
1901	.20	.35	3.23	2.26	.63	1.90	.25	2.71	4.13	.45	.31	.41	16.83
1902	.35	.25	1.25	1.03	4.27	4.19	4.90	1.13	3.47	2.07	.10	.80	23.81
1903	.30	1.70	.58	.90	6.73	1.75	4.05	2.69	.77	.12	.77	.09	20.45
1904	.09	.12	.55	.99	4.80	5.76	1.60	2.44	1.98	1.41	.05	.27	20.06
1905	.48	.50	1.51	3.04	4.15	4.35	5.09	1.53	2.83	1.80	.83	.00	26.11
1906	.32	.40	1.53	3.48	1.14	1.01	2.38	2.60	.87	2.74	.48	.84	17.79

STRATTON, HITCHCOCK COUNTY.

Normal	0.31	0.75	1.20	2.39	2.97	3.59	2.76	2.24	2.08	1.34	0.60	0.35	20.58
1896	.42	.05	.50	3.85	1.96	2.80	1.07	1.45	1.20	1.25	.08	.10	14.73
1897	.59	.52	2.22	2.50	.45	3.29	1.45	2.97	.90	4.35	.24	.64	20.12
1898	.17	.00	.24	3.23	4.53	2.86	2.52	.71	4.48	.85	.29	.18	20.06
1899	.49	.36	.90	.42	1.61	3.02	2.64	2.04	.20	.07	2.54	.14	14.43
1900	.00	1.25	.38	3.82	.77	4.34	3.30	1.59	.37	.10	.30	.20	16.42
1901	.20	.90	4.46	3.00	.76	4.45	2.15	4.02	3.05	.57	.66	.73	24.95
1902	.31	.38	.74	1.02	5.31	3.35	4.63	2.26	4.77	1.60	.17	1.30	25.84
1903	.28	2.90	.45	.80	6.00	1.16	2.26	2.96	.76	.25	.91	.01	18.74
1904	.12	.15	.48	1.50	4.08	5.74	2.69	2.18	1.89	2.96	.02	.21	22.02
1905	.50	.95	1.68	3.80	4.23	4.87	4.85	2.24	3.16	1.45	.80	.00	28.53
1906	.30	.40	1.83	2.93	1.90	.78	1.73	3.67	.74	1.37	1.25	.40	17.30

HAYES CENTER, HAYES COUNTY.

Normal	0.49	1.18	1.45	2.81	3.22	3.33	2.70	2.75	1.98	1.48	0.56	0.35	21.30
1896	.75	.....	1.20	3.43	1.56	3.31	2.12	2.54	1.63	1.45	.25	.30	.....
1897	.20	.34	1.86	3.36	.37	4.36	2.09	2.32	1.19	3.22	.30	.50	20.11
1898	.45	.25	.40	3.65	3.25	3.85	1.85	1.24	3.65	.....	.60	T.	.....
1899	.50	1.28	1.33	.34	3.24	1.52	3.36	2.18	.12	T.	2.10	.11	16.08
1900	.02	1.67	.46	3.07	1.78	1.32	4.24	3.96	.05	T.	.15	.20	16.92
1901	.10	.80	2.35	3.04	.75	3.80	.58	3.35	3.42	.59	.00	.35	19.13
1902	.20	.46	1.33	.96	6.02	3.72	2.05	2.39	5.00	1.85	T.	1.45	25.43
1903	.28	3.83	T.	1.42	5.48	.94	4.15	2.74	.64	.80	.44	.10	20.82
1904	.22	.20	.50	1.14	4.78	5.80	2.95	3.51	1.57	2.22	.07	.15	23.11
1905	1.00	1.50	2.52	4.46	4.92	4.87	5.39	2.50	1.95	2.75	1.00	.00	32.86
1906	.60	.40	4.42	7.75	3.15	1.70	.77	3.31	.78	2.45	.70	.90	26.93

Precipitation at stations in drainage basin of Republican River, 1896–1906—Continued.

IMPERIAL, CHASE COUNTY.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.41	0.83	1.49	2.60	3.00	3.55	3.07	2.51	1.65	1.05	0.44	0.53	20.93
1896	.50	.20	1.10	4.30	1.34	4.60	3.15	1.45	1.40	1.00	.20	.35	19.59
1897	.50	.70	2.05	2.55	1.95	2.38	1.23	6.03	.51	3.87	.52	.70	22.99
1898	.50	.22	.56	1.82	7.29	3.55	3.37	.88	4.02	.30	.86	.92	24.29
1899	1.00	.92	1.90	.64	2.44	4.22	3.12	.93	.18	.19	1.94	.08	17.56
1900	.07	2.24	1.08	3.96	1.47	2.43	4.87	3.47	.13	T.	.22	.15	20.09
1901	T.	.34	2.43	4.42	1.26	3.57	1.50	2.76	1.83	1.00	T.	.85	19.96
1902	.41	.42	1.65	.97	3.58	4.67	3.86	1.42	4.24	1.25	.12	1.84	24.43
1903	.22	2.75	.30	.70	3.17	1.33	4.87	2.67	.02	.30	.59	T.	16.92
1904	.06	.02	.13	2.71	4.57	8.18	3.62	2.12	1.57	2.03	.10	.36	25.47
1905	.84	.93	3.82	3.55	5.65	4.78	6.38	2.52	2.75	1.58	.50	.05	33.35
1906	.65	.52	3.38	5.97	2.43	1.54	2.67	2.67	2.80	2.47	.78	.45	26.33

WALLACE, LINCOLN COUNTY.

Normal	0.52	0.62	1.05	1.91	2.46	3.18	2.50	1.57	0.75	0.43	0.13	0.27	15.39
1896	.50	.20	2.60	4.59	.80	3.38	6.06	1.86	.96	.70	.10	.50	22.25
1897	.23	.50	1.35	2.23	T.	1.46	.86	1.62	.12	.60	.50	.70	10.17
1898	1.05	.10	.30	.55	4.80	2.26	.....	.....	.....	.....	.....	.02	.....
1899	.76	.80	.91	.10	4.65	2.63	2.95	.60	.20	.15	.00	.20	13.95
1900	.00	1.17	.....	2.47	1.55	2.24	3.05	1.24	.00	.00	.10	.15	.....
1901	.04	.35	2.25	1.45	1.61	4.33	.00	.54	2.45	.00	.00	.30	.....
1902	.42	.65	1.05	1.98	3.10	3.62	1.75	2.00	3.25	1.25	.00	.80	19.87
1903	.20	1.10	T.	.30	3.69	1.30	3.76	3.24	.30	.30	.40	.00	14.59
1904	.45	.30	.20	1.65	4.20	4.13	2.41	1.42	1.60	.....	.00	.....	.....
1905	.....	.80	2.95	2.80	4.92	5.10	4.75	2.05	1.05	.....	.25	.00	.....
1906	.60	.....	.....	4.25	.....	2.20	.....	.....	.....	.....	.....	.....	.....

MADRID, PERKINS COUNTY.

Normal	0.35	0.79	0.85	1.67	2.36	3.31	1.95	1.76	0.60	0.56	0.37	0.41	14.98
1896	.50	.20	1.90	4.13	1.78	3.75	.90	2.10	.95	.80	.10	.40	17.51
1897	T.	.20	1.36	2.19	.88	1.52	1.30	2.19	.22	2.63	T.	.95	13.44
1898	.75	.20	.30	.64	4.08	1.78	.63	1.50	2.75	T.	.80	.20	13.63
1899	.60	.60	1.10	.30	2.75	1.73	2.95	.99	.00	.14	.88	.10	12.14
1900	.02	1.30	.20	2.15	1.75	3.75	2.25	2.03	T.	.10	.00	.00	13.55
1901	.20	.70	1.90	2.80	2.18	4.38	.31	2.14	1.07	.26	.00	.30	16.24
1902	.50	.30	1.00	1.15	4.25	3.15	3.50	.....	.....	.75	.20	.90	.....
1903	.20	2.10	.10	.....	3.82	1.47	4.06	2.03	.00	.....	.36	.30	.....
1904	T.	.20	.25	1.64	.....	3.49	3.71	.....	.....	.....	.....	.....	.....
1905	.17	.51	2.40	3.61	4.04	5.03	4.28	3.49	2.26	.96	.41	.00	27.16
1906	.15	1.20	2.54	3.43	3.02	3.51	2.67	2.76	1.78	1.80	.43	.41	23.70

BENKELMAN, DUNDY COUNTY.

Normal	0.26	0.72	0.88	2.37	2.90	3.58	2.48	2.36	2.16	0.65	0.37	0.34	19.07
1896	.22	.10	.70	3.53	2.82	2.78	.62	1.47	.75	.80	T.	.15	13.24
1897	.08	.57	1.18	1.12	.25	3.66	2.03	3.78	1.65	2.60	.15	.45	17.52
1898	.20	T.	.40	3.47	5.31	3.26	2.85	.90	3.20	1.13	T.	T.	20.72
1899	.40	.40	.87	.20	1.25	.90	2.42	2.73	T.	T.	1.75	.30	11.12
1900	T.	1.00	.20	3.43	.74	4.88	2.29	2.31	.06	T.	.15	.18	15.24
1901	.10	.40	4.25	3.05	1.25	6.27	.....	4.95	8.70	.45	.15	.80	.....
1902	.25	.38	1.00	1.01	7.77	2.70	4.00	1.93	3.70	.....	.00	1.50	.....
1903	.50	2.95	.08	.85	4.97	2.34	1.96	2.28	1.10	.24	.61	.10	17.98
1904	.29	.39	.05	2.29	2.12	4.46	2.69	2.03	2.45	.....	T.	.01	.....
1905	.40	.....	.....	2.39	3.20	3.10	4.00	.....	.....	.....	.....	T.	.....
1906	.60	.....	2.30	.....	.....	.....	.58	.....	1.05	.....	.....	.19	.....

Precipitation at stations in drainage basin of Republican River, 1896–1906—Continued.

HAIGLER, DUNDY COUNTY.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.17	0.37	0.62	2.04	2.41	2.81	2.50	2.30	1.04	0.59	0.30	0.27	15.42
1896	.42	.10	.85	2.67	3.14	3.75	1.70	.94	.85	.60	.02	.52	15.56
1897	T.	T.	.70	2.58	1.62	4.56	.97	4.15	.51	1.80	.40	.20	17.49
1898	.00	T.	.70	3.08	3.38	4.18	1.20	1.75	3.20	.80	T.	T.	18.29
1899	.30	T.	.52	.87	2.13	3.23	2.87	1.31	.00	.00	1.70	.50	13.43
1900	T.	.70	.25	6.05	.60	3.23	2.55	4.54	.00	T.	.05	.30	18.27
1901	.05	.30	1.55	3.55	.25	1.71	1.66	5.69	1.80	T.	.00	.50	17.06
1902	.20	.10	1.12	.65	5.68	2.16	2.20	2.32	2.61	2.36	T.	.50	19.90
1903	.20				2.98	1.76			.82	.32		.10	
1904	.02	.06	.10				1.46	1.18	3.13	1.35	.02	.03	
1905	.56	.37	2 30	2.48							.27	.00	
1906	.23	.25	1.55	3.10	1.50	2.50	4.55	2.50	1.60	1.00	.05	T.	18.83

WRAY, YUMA COUNTY, COLO.

Normal	0.35	0.59	1.07	2.49	2.73	3.29	2.52	1.89	1.42	0.74	0.26	0.33	17.68
1890			T.	T.	4.44	1.42	.62	.25	1.09	.45	.25	T.	
1891	1.80	.50	1.90	4.68	2.02	4.55	2.52	.45	1.24	0	.20	.83	20.69
1893				.03	2.12	1.00							
1895										T.	.12	.32	
1896	.47	.02	.66	4.83	1.64	3.77	1.13	1.47	1.01	1.37	.06	.20	16.63
1897	.28	.26	1.79	1.64	3.34	4.79	1.79	2.27	.73	2.92	.07	.31	20.19
1898	.06	.07	.83	1.73	5.47	2.98	1.88	2.56	2.33	.25	.26	.29	18.71
1899	.63	.07	.50	.62	1.96	1.83	2.18	1.38	.08	T.	1.16	.33	10.74
1900	.16	.90	.33	6.00	.61	2.35	4.57	2.60	.15	.03	.20	.34	18.24
1901	T.	1.37	2.51	4.02	.28	3.40	2.05	5.36	2.11	.43	T.	.91	22.44
1902	.20	.74	1.05	.74	7.00	5.69	3.33	2.71	3.73	1.05	.16	.59	26.99
1903	.25	1.98	.16	.54	1.95	1.55	5.16	1.48	.69	.34	.25	T.	14.35
1904	T.	.58	.04	2.46	2.02	6.25	2.00	1.26	1.74	1.19	.05	.20	17.79
1905	.04	.05	3.10	5.12	2.59	3.19	2.98	.93	2.19	1.64	.60	T.	22.43
1906	.55	.62	1.88	4.82	3.20	2.57	1.62	3.57	1.71	1.43	.83	.29	23.09

YUMA, YUMA COUNTY, COLO.

Normal	0.54	0.86	1.41	2.31	2.54	2.79	2.48	2.15	0.93	0.63	0.33	0.53	17.50
1891	2.35	.50	3.63	2.90	4.21	5.23	2.98	.75	.64	.05	.13	1.25	24.62
1892	.80	1.55	.80	3.20	3.46	1.20	4.44	1.50	.35	1.00	T.	.62	18.92
1893	T.	.90	.70	.38	2.57	1.30	2.10	.95	T.	.40	.41	.55	10.26
1894	.50	.90	1.10	.68	.04	1.85	.80	.70	2.85	0	22	.70	10.34
1895	1.20	1.70	.50	1.10	2.76	2.73	3.22	1.77	.55	.10	.60	.10	16.33
1896	.60	.20	1.25	1.82	2.06	3.98	2.59	1.04	1.02	.78	.30	.20	15.84
1897	.37	.40	2.80	.80	1.62	4.44	1.78	2.44	T.	2.55	.10	1.00	18.30
1898	.30	.20	.31	1.55	5.80	2.70	1.86	3.62	1.00	1.50	1.45	1.10	20.39
1899	1.38	.60	1.18	.97	1.23	3.03	2.63	2.22	.17	.03	.90	.27	14.61
1900	.14	1.55	.61	8.67	1.39	.72	1.81	2.22	.16	.03	.17	.51	17.98
1901	T.	1.11	2.44	3.90	.31	3.51	1.61	6.53	.36	.39	T.	.57	20.73
1902	.07	.56	.95	.67	3.76	1.91	2.70	3.33	1.68	.78	.20	.73	17.34
1903	.14	1.88	.20	.40	1.00	2.10	2.65	3.12	.35	.10	.36	.09	12.39
1904	T.	.70	.25	3.37	4.26	4.98	1.65	1.28	2.92	1.07	T.	.27	20.75
1905	.31	.13	4.47	4.27	3.64	2.16	4.45	.73	1.91	1.64	.05	0	23.76
1906	.38	.51	2.36	4.45	2.01	1.98	2.44	1.23	1.19	2.92	1.17	.12	20.76

Precipitation at stations in drainage basin of Republican River, 1896–1906—Continued.

LEROY, LOGAN COUNTY, COLO.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.42	0.75	1.04	2.47	2.54	2.19	1.95	1.94	0.95	0.78	0.27	0.42	15.72
1889				4.40	2.09	3.38	.36	2.56	.83	.37	.60	.10	
1890	.30	.48	.01	2.80	1.03	1.96	.47	1.41	T.	.98	.48	.01	9.93
1891	1.70	1.00	1.99	1.35	5.02	4.84	4.69	2.89	.67	.14	.37	.94	25.60
1892	.89	2.24	.80	4.02	2.53	1.48	3.07	1.83	.84	1.66	.10	.65	20.11
1893	.05	1.20	.87	.46	2.73	1.25	1.75	.61	.41	.41	.48	.94	11.16
1894	.35	.46	.95	.98	.17	.75	1.16	.47	1.06	.08	.26	.65	7.34
1895	.73	.88	.40	2.43	2.05	2.94	2.56	.79	.42	.11	.47	.12	13.90
1896	.53	.24	1.20	1.91	2.36	3.77	1.33	.87	.86	.90	.20	.01	14.18
1897	.60	.72	1.66	1.77	3.08	2.24	1.39	2.79	.41	2.61	.40	.81	18.48
1898	.38	.26	.67	1.07	4.60	1.31	2.83	1.13	1.27	.54	.65	.27	14.95
1899	.50	.33	1.21	1.57	2.93	.28	2.17	2.38	.88	.30	.23	.44	13.22
1900	.10	.96	.12	7.27	2.10	.78	1.68	.99	.35	.07	.12	.20	14.74
1901	.06	.49	1.60	2.92	.72	2.52	.97	4.03	.27	.47	T.	.89	14.94
1902	.12	.72	1.23	1.28	3.16	1.82	.98	3.70	3.46	.78	.09	.99	18.33
1903	.18	1.50	.26	1.12	.80	1.07	1.71	3.44	.62	.29	.06	.03	11.08
1904	.10	.26	.35	1.99	3.97	4.39	3.46	1.17	2.96	1.55	.04	.05	20.29
1905	.17	.30	3.28	4.70	3.88	2.48	2.56	1.96	.78	1.93	.12	.02	22.18
1906	.23	.43	1.38	4.53	1.96	1.35	1.88	2.83	2.70	2.69	1.29	.53	21.80

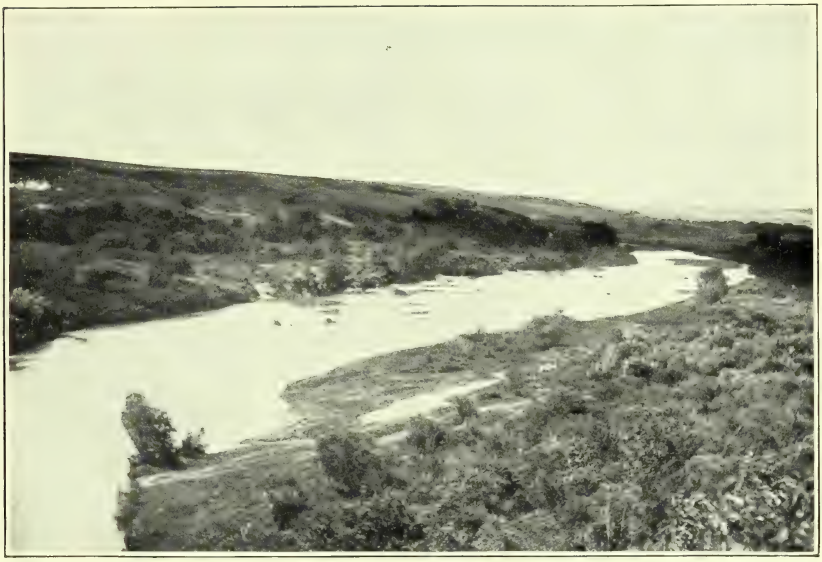
NIOBRARA RIVER DRAINAGE BASIN.

DESCRIPTION OF BASIN.

Niobrara River rises in the mountains of eastern Wyoming, flows eastward across northern Nebraska, and unites with the Missouri in Knox County, at the city of Niobrara. Its drainage area, comprising about 9,000 square miles, is comparatively narrow in its upper portion, but broadens considerably as the river approaches the Missouri. Near the headwaters the flood plain is about 400 feet above North Platte River.

In its middle course the river runs in a canyon 100 to 300 feet deep (Pl. III), beyond which are high, rolling or broken table-lands, cut by deep canyons of the numerous tributary streams. Bordering the table-lands are rolling sand hills which cover large portions of Sheridan, Cherry, Brown, Rock, and Holt counties. Formerly these sand hills were migratory, being blown hither and thither by winds; but in recent years, owing, perhaps, partly to increased rainfall and partly to a diminution in the herds of cattle which roam over these lands, they have become overgrown with a comparatively luxuriant growth of grasses that render them more permanent and provide excellent range.

Geologically, the valley from Valentine westward exhibits a comparatively narrow strip of calcareous grit and gray sand with beds of pipy concretions, popularly called magnesia. From Valentine eastward this formation gives place to slate-colored clays and soft shales,

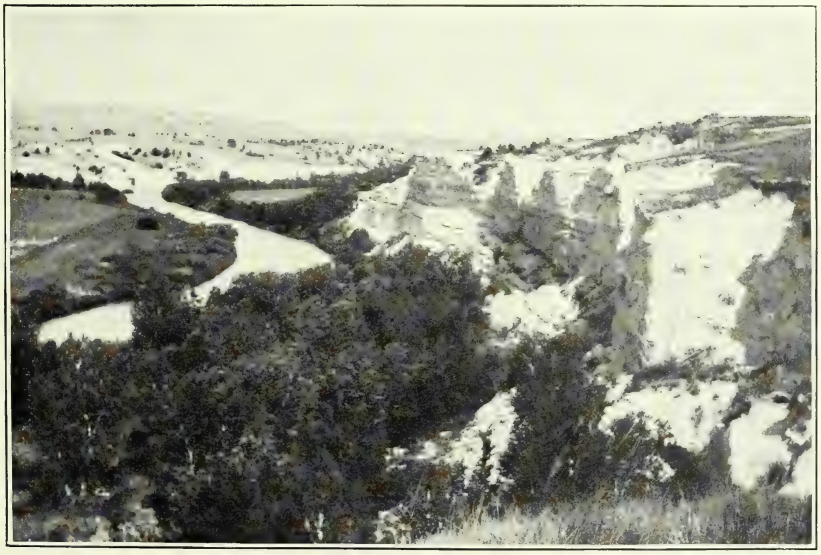


A

B

CANYONS OF NIOBRARA RIVER.

A. RESERVOIR AND POWER PLANT ON MINNECHADUZA CREEK.



B. NIOBRARA RIVER AND "CHALK BLUFFS."

with some chalky limestone and shale beds near the mouth of the river (Pl. IV, *B*). Outside of this strip, particularly on the south, are the sand hills mentioned above.

The soil throughout the region is predominantly sandy, and trees are rare, though a few cedars cling to the sides of the canyons of the main stream and its tributaries. The Niobrara National Forest, which lies between Niobrara and Snake rivers, consists almost wholly of sand hills, except along the borders. No forests of any extent exist at present. The greater part of the drainage area of this stream is given over to range land for cattle. Between the sand hills and lying in a generally east-west direction are extensive hay flats, and on the firmer soils considerable farming is done. The annual precipitation is small, but as the greater part of it falls during the growing months, comparatively large quantities of corn, wheat, melons, etc., are produced. In the eastern part of the drainage area, through Boyd, Keyapaha, and the northern parts of Brown, Rock, and Holt counties, the country is largely given to farming, and nearly all the crops characteristic of the more eastern portions of the State are successfully grown. Numerous groves have been planted, and natural timber is abundant along this portion of the stream and its tributaries.

Precipitation varies from 15 to 18 inches annually in the upper part of the drainage area, from 18 to 21 inches in the middle part, and from 21 to 24 inches along the lower course of the stream. Evaporation amounts to 6, 5, and 4½ feet in the upper, middle, and lower areas, respectively. About 70 per cent of the precipitation falls in the months from April to August, inclusive, and about one-half of the remainder is snowfall.

The chief tributaries of the Niobrara are Verdigris, Keyapaha, and Snake rivers and Minnechaduza Creek. The drainage area of the Snake is similar in most respects to that of the western portion of the Niobrara. Little damage is done by floods, for the sand hills that form a large portion of the drainage area act as storage reservoirs for the rain and snowfall, feeding it to the stream in the form of spring water, and thus equalizing the flow and producing a constancy of discharge that is almost phenomenal. The sand-hill lakes so numerous in the southern part of this drainage area, of which Red Deer Lake is typical, are described on pages 231–232.

At present the waters of the Niobrara are almost wholly undeveloped. Irrigation is restricted to the low, narrow flood plain at the bottom of the canyon, and the ditches are small and rude. A dam on Minnechaduza Creek at Valentine forms an artificial lake, and a power plant has been installed for lighting and furnishing the city with water (Pl. IV, *A*). Along the lower course of the Niobrara

a number of small mills are in operation, obtaining their power from small tributaries. On Snake River possibilities for power development are remarkable, but long transmission lines would be required to make these of practical value. (See Pls. V and VI.)

More detailed information concerning the characteristics of the Niobrara drainage area is given in a report on a reconnaissance of Niobrara River and its tributaries by the author of this paper, published in the Third Annual Report of the United States Reclamation Service, pages 326 et seq., and in a preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian by N. H. Darton, published in the Nineteenth Annual Report of the United States Geological Survey, part 4, pages 719 et seq.

The following table shows the stations maintained in this drainage basin:

Gaging stations in Niobrara River drainage basin.

Stream.	Station.	Established.	Discontinued.
Niobrara	Valentine	July 22, 1897	
Do	Niobrara	May 11, 1902	Oct. 25, 1902
Red Deer Lake	Woodlake	Aug. 12, 1904	Oct. 31, 1905

NIOBRARA RIVER NEAR VALENTINE.

The station known as Fort Niobrara station was established July 22, 1897. June 26, 1901, it was moved about 3 miles farther upstream to the Borman Bridge, in sec. 4, T. 34 N., R. 28 W., about 3 miles southeast of the town of Valentine.

At the gaging station the stream lies on an easy curve. The banks are heavily wooded and high and are not liable to overflow. The bed is composed of cobblestones and sand, which at times of high water scours out, leaving the rocks comparatively bare. The shifting of the sand renders the development of a good rating curve a difficult matter, and the method of applying a rating table indirectly has been largely used. There are no natural obstructions in the stream and the current is always swift. The range of gage heights seldom exceeds 2 feet except after a "cloud-burst," when the very lowest bottom land has been flooded for a few hours. The river seldom freezes completely over, and during 1904 and 1905 records of gage heights were obtained throughout the winter.

Discharge measurements are made from a single-span steel bridge.

The gage is of the wire and weight type, and is located about 1,000 feet upstream from the bridge on the left bank. The length of the wire is 9.90 feet. The gage is referred to bench marks as follows:

FALLS OF SNAKE RIVER.

(1) The head of a nail driven in the stump of a boxelder tree—one of a clump of four—just east of Mr. Borman's house; elevation 17.26 feet above the zero of the gage. (2) A 2- by 6-inch pine head block, on which the gate of Borman's fence rests when closed; elevation 16.19 feet above the zero of the gage. As a check, the elevation of the water surface at the time of making the measurements is referred to the bottom of the upstream end of the second floor beam from the end of the bridge on the left bank.

Discharge measurements of Niobrara River near Valentine, 1897–1906.

Date.	Hydrographer.	Gage height.	Discharge.
1897.[a]		*Feet.*	*Sec.-ft.*
June 24	O. V. P. Stout	0.59	925
July 22	do	.48	883
August 15	do	.38	703
September 5	do	.46	730
October 16	Adna Dobson	.21	845
1898.[a]			
April 25	Glenn E. Smith	.05	987
May 13	do	.23	1,588
May 24	do	.10	1,156
June 12	do	.05	876
July 27	do	.35	690
August 21	do	.39	677
September 7	do	.32	748
September 26	do	.28	840
October 16	do	.18	867
October 29	do	.12	960
November 17	do	.5	960
December 17	do	Ice.	843
December 28	do	Ice.	964
1899.[a]			
January 27	do	Ice.	623
March 15	do	Ice.	726
Do	do	Ice.	[b]650
April 25	do	1.15	952
May 11	do	1.18	867
May 26	do	1.44	1,031
June 23	do	1.24	733
July 16	do	1.52	788
August 13	do	1.30	718
August 30	do	1.35	700
September 13	do	1.15	695
September 26	do	1.05	732
October 7	do	1.15	776
October 20	do	.80	849
1901.			
June 26	O. V. P. Stout	1.46	724
August 1	do	1.45	951
May 12	C. B. Channel		628
November 14	B. E. Forbes	1.54	818
1902.			
March 22	J. C. Stevens	1.66	971
April 12	do	1.50	785
1902.		*Feet.*	*Sec.-ft.*
June 15	J. C. Stevens	1.30	585
July 4	do	1.60	800
July 20	do	1.40	727
August 20	do	1.40	681
September 26	do	1.55	733
November 13	do	1.60	764
1903.			
April 26	do	1.55	766
May 26	do	1.55	878
May 26	do	1.55	894
June 25	do	1.40	714
August 25	do	1.30	602
September 17	E. C. Murphy	1.38	709
Do	do	1.38	715
December 23	J. C. Stevens	1.75	706
1904.			
April 17	do	1.57	683
Do	do	1.57	640
July 11	do	1.44	761
Do	do	1.47	760
Do	do	1.48	756
Do	do	1.51	752
Do	do	1.53	801
August 11	do	1.26	584
August 24	do	1.30	638
1905.			
March 13	E. L. Thomas	1.64	910
May 31	H. C. Gardner	1.85	1,142
June 29	do	1.80	1,111
July 19	G. W. Bates	1.50	818
August 15	H. C. Gardner	1.65	978
October 15	do	1.55	834
November 15	G. W. Bates	1.65	886
December 27	do	1.75	940
1906.			
March 14	Geo. W. Bates	1.55	[c]483
April 18	do	1.10	1,121
May 1	do	1.75	998
May 11	do	1.65	819
June 30	F. S. Dobson	1.35	627
September 21	Adna Dobson	1.45	813
December 17	Geo. W. Bates	1.70	776

[a] Measurements during 1897, 1898, and 1899, made at Fort Niobrara, 3 miles below present station.
[b] Measurement made 3 miles below Fort Niobrara Bridge.
[c] Slush ice running and edges frozen.

Mean daily gage height, in feet, of Niobrara River near Valentine, 1897–1906.

Day.	July.	Aug.	Sept.	Oct.	Day.	July.	Aug.	Sept.	Oct.
1897.					1897.				
1	.....	0.33	0.41	0.42	17	.....	0.39	0.41	0.17
2	.....	.30	.38	.40	18	.....	.32	.37	.20
3	.....	.45	.36	.40	19	.....	.31	.39	.15
4	.....	.41	.41	.40	20	.....	.31	.36	.14
5	.....	.50	.46	.40	21	.....	.39	.38	.12
6	.....	.50	.41	.38	22	0.51	.39	.45	.19
7	.....	.46	.39	.35	23	.46	.38	.45	.22
8	.....	.47	.34	.30	24	.50	.34	.46	.23
9	.....	.40	.45	.31	25	.44	.31	.48	.28
10	.....	.50	.47	.32	26	.41	.32	.....	.37
11	.....	.34	.45	.32	27	.44	.32	.....	.29
12	.....	.40	.45	.26	28	.44	.32	.....	.22
13	.....	.36	.49	.27	29	.44	.31	.45	.15
14	.....	.37	.50	.23	30	.40	.32	.44	.12
15	.....	.36	.42	.21	31	.40	.39	.....	.....
16	.....	.29	.45	.20					

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Day.	Apr.	May.	June.	July.	Aug.	Sept.
1899.							1899.						
1	.....	1.13	1.31	1.21	1.31	1.24	17	.....	1.12	1.41	1.51	1.41	1.24
2	.....	1.11	1.31	1.41	1.34	1.24	18	.....	1.14	1.41	1.44	1.44	1.21
3	.....	1.12	1.34	1.34	1.51	1.31	19	.....	1.21	1.34	1.41	1.41	1.14
4	.....	1.12	1.31	1.23	1.41	1.31	20	.....	1.22	1.24	1.41	1.34	1.14
5	.....	1.14	1.31	1.24	1.34	1.24	21	.....	1.23	1.23	1.41	1.32	1.24
6	.....	1.21	1.21	1.34	1.34	1.21	22	.....	1.24	1.23	1.31	1.34	1.21
7	.....	1.13	1.14	1.41	1.31	1.21	23	.....	1.34	1.22	1.31	1.34	1.11
8	.....	1.24	1.12	1.41	1.31	1.21	24	.....	1.44	1.22	1.31	1.34	1.11
9	.....	1.31	1.12	1.41	1.41	1.24	25	.....	1.34	1.51	1.24	1.24	1.14
10	.....	1.14	1.12	1.42	1.34	1.21	26	1.14	1.44	1.21	1.21	1.24	1.12
11	.....	1.14	1.24	1.44	1.31	1.21	27	1.14	1.41	1.31	1.24	1.24	1.14
12	.....	1.14	1.44	1.44	1.34	1.14	28	1.21	1.42	1.34	1.24	1.24	1.11
13	.....	1.14	1.34	1.51	1.41	1.14	29	1.21	1.41	1.34	1.31	1.31	1.11
14	.....	1.14	1.21	1.42	1.21	1.14	30	1.13	1.42	1.41	1.31	1.31	1.11
15	.....	1.14	1.21	1.51	1.31	1.24	31	.....	1.31	.....	1.31	1.21	.....
16	.....	1.11	1.24	1.54	1.41	1.21							

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Day.	June.	July.	Aug.	Sept.	Oct.	Nov.
1901.							1901.						
1	.....	1.61	1.35	1.55	1.38	1.53	17	.....	1.22	1.32	1.45	1.45	1.67
2	.....	1.35	1.40	1.50	1.46	1.49	18	.....	1.20	1.30	1.36	1.49	1.63
3	.....	1.37	1.40	1.47	1.48	1.47	19	.....	1.40	1.27	1.42	1.55	1.65
4	.....	1.32	1.38	1.75	1.46	1.46	20	.....	1.35	1.25	1.38	1.54	1.70
5	.....	1.30	1.30	1.62	1.40	1.53	21	.....	1.25	1.40	1.33	1.49	1.63
6	.....	1.28	1.32	1.42	1.43	1.49	22	.....	1.22	1.35	1.45	1.48	1.68
7	.....	1.24	1.28	2.68	1.52	1.51	23	.....	1.18	1.29	1.36	1.46	1.65
8	.....	1.25	1.25	1.80	1.55	1.50	24	.....	1.15	1.40	1.45	1.52	1.66
9	.....	1.40	1.29	1.65	1.63	1.55	25	.....	1.25	1.35	1.43	1.45	1.65
10	.....	1.30	1.35	1.53	1.90	1.50	26	.....	1.30	1.45	1.35	1.50	1.66
11	.....	1.35	1.40	1.60	1.70	1.68	27	1.45	1.40	1.38	1.43	1.45	1.64
12	.....	1.30	1.25	1.58	1.68	1.70	28	1.38	1.35	1.39	1.48	1.45	1.65
13	.....	1.20	1.28	1.53	1.65	1.63	29	1.37	1.30	1.38	1.45	1.51	1.69
14	.....	1.21	1.40	1.58	1.55	1.54	30	1.36	1.33	1.40	1.40	1.52	1.70
15	.....	1.20	1.30	1.50	1.52	1.70	31	.....	1.30	1.55	.....	1.54	.....
16	.....	1.18	1.35	1.52	1.53	1.68							

DAM SITE ON SNAKE RIVER.

Mean daily gage height, in feet, of Niobrara River near Valentine, 1897–1906 Cont'd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1				1.58	1.63	1.50	3.10	1.31	1.40	1.43	1.58	1.55
2				1.61	1.65	1.42	1.95	1.32	1.38	1.47	1.64	1.46
3				1.64	1.60	1.44	1.73	1.38	1.30	1.42	1.53	1.16
4				1.70	1.58	1.45	1.56	1.31	1.27	1.44	1.50	1.40
5				1.68	1.65	1.54	1.58	1.42	1.28	1.47	1.57	1.48
6				1.75	1.53	1.55	1.38	1.38	1.30	1.45	1.55	1.55
7				1.50	1.47	1.44	1.25	1.31	1.27	1.44	1.54	.....
8				1.58	1.56	1.58	1.90	1.43	1.41	1.45	1.58	.....
9				1.54	1.60	1.42	1.38	1.48	1.28	1.46	1.54	.....
10			1.78	1.55	1.54	1.40	1.32	1.40	1.26	1.51	1.52	.....
11			1.80	1.44	1.52	1.42	1.32	1.24	1.33	1.53	1.50	.....
12			1.75	1.54	1.64	1.50	1.36	1.20	1.32	1.55	1.56	.....
13			1.79	1.58	1.57	1.48	1.27	1.36	1.29	1.52	1.60	.....
14			1.67	1.60	1.55	1.40	1.32	1.38	1.37	1.49	1.58	.....
15			1.65	1.54	1.63	1.28	1.26	1.39	1.33	1.48	1.56	.....
16			1.40	1.64	1.47	1.42	1.25	1.38	1.35	1.55	1.62	.....
17			1.33	1.72	1.52	1.47	1.26	1.44	1.34	1.52	1.56	.....
18			1.60	1.66	1.49	1.34	1.40	1.37	1.45	1.48	1.61	.....
19			1.95	1.58	1.83	1.52	1.42	1.38	1.40	1.50	1.54	.....
20			1.85	1.56	1.78	1.47	1.40	1.34	1.48	1.49	1.57	.....
21			2.05	1.47	1.51	1.36	1.34	1.45	1.45	1.48	1.50	.....
22			1.66	1.74	1.45	1.80	1.32	1.43	1.47	1.51	1.56	.....
23			1.75	1.69	1.51	1.32	1.37	1.34	1.33	1.55	1.52	.....
24			1.98	1.52	1.46	1.36	1.41	1.43	1.37	1.50	1.53	.....
25			1.90	1.80	1.44	1.33	1.32	1.62	1.48	1.51	1.60	.....
26			1.96	1.75	1.42	1.34	1.38	1.45	1.59	1.56	1.51	.....
27			1.93	1.54	1.48	1.37	1.35	1.31	1.53	1.53	1.56	.....
28			1.89	1.72	1.37	1.46	1.32	1.38	1.45	1.52	1.53	.....
29			1.83	1.58	1.40	1.95	1.34	1.40	1.57	1.51	1.46	.....
30			1.97	1.65	1.33	2.10	1.45	1.43	1.42	1.54	1.48	.....
31			1.85	.....	1.42	.....	1.36	1.52	.....	1.50	.....	.....
1903.												
1			1.18	1.90	1.50	1.50	1.40	1.56	1.30	1.38	1.52	1.58
2			1.67	1.94	1.52	1.43	1.37	1.95	1.33	1.41	1.50	1.62
3			1.90	1.92	1.50	1.42	1.35	3.20	1.31	1.45	1.51	1.57
4			1.75	1.80	1.55	1.47	1.37	1.60	1.37	1.38	1.55	1.60
5			1.80	1.85	1.55	1.43	1.30	1.51	1.29	1.42	1.46	.....
6			1.78	1.65	1.57	1.40	1.33	1.25	1.32	1.41	1.50	1.55
7			1.90	1.63	1.62	1.38	1.30	1.26	1.35	1.40	1.50	1.60
8			1.95	1.65	1.60	1.44	1.30	1.27	1.33	1.32	1.50	1.62
9			1.98	1.68	1.61	1.48	1.29	1.20	1.31	1.34	1.52	1.68
10			2.10	1.85	1.72	1.39	1.31	1.22	1.32	1.35	1.50	1.62
11			2.05	1.70	1.68	1.41	1.33	1.24	1.29	1.44	1.52	1.61
12			2.13	1.58	1.55	1.31	1.35	1.28	1.32	1.50	1.56	1.60
13			2.15	1.62	1.53	1.28	1.32	1.30	1.33	1.42	1.58	1.51
14			2.10	1.60	1.48	1.30	1.38	1.42	1.35	1.43	1.55	1.41
15		1.26	2.05	1.52	1.47	1.32	1.40	1.35	1.43	1.45	1.60	1.45
16		1.22	1.98	1.57	1.45	1.30	1.37	1.40	1.40	1.51	.....	1.65
17		1.13	2.02	1.60	1.50	1.34	2.12	1.39	1.38	1.40	.....	1.80
18		1.56	2.05	1.68	1.51	1.30	3.37	1.35	1.37	1.41	.....	1.82
19		1.66	2.03	1.90	1.48	1.42	2.00	1.33	1.35	1.39	.....	1.88
20		1.75	1.78	1.87	1.45	1.35	1.55	1.34	1.38	1.42	.....	1.82
21		1.84	1.85	1.75	1.47	1.52	1.41	1.33	1.41	1.45	.....	1.89
22		1.95	1.72	1.70	1.45	1.35	1.35	1.34	1.45	1.48	1.80	1.78
23		1.70	1.80	1.72	1.40	1.48	1.34	1.31	1.34	1.48	1.75	1.80
24		1.83	1.75	1.58	1.42	1.40	1.32	1.32	1.35	1.47	1.65	1.79
25		1.76	1.78	1.63	1.38	1.40	1.33	1.29	1.42	1.45	1.62	1.90
26		1.98	1.96	1.55	1.57	1.35	1.35	1.35	1.40	1.40	1.60	2.00
27		1.95	1.95	1.53	1.40	1.36	1.30	1.45	1.34	1.45	1.62	1.80
28		1.42	1.90	1.65	1.40	1.40	1.25	1.37	1.36	1.48	1.63	1.75
29		.....	1.88	1.60	1.50	1.35	1.30	1.33	1.40	1.49	1.57	1.74
30		.....	1.85	1.57	1.41	1.33	1.36	1.27	1.45	1.47	1.52	1.72
31		.....	1.88	.....	1.42	.....	1.47	1.31	.....	1.48	.....	1.73
1904.												
1	1.65	2.30	2.05	1.56	1.55	1.86	1.35	1.30	1.54	1.51	1.55	1.54
2	1.74	2.25	1.90	1.53	1.60	1.78	1.35	1.60	1.36	1.50	1.52	1.51
3	1.63	2.35	1.55	1.55	1.55	2.05	1.37	1.33	1.37	1.55	1.53	1.50
4	1.67	2.15	1.80	1.57	1.75	1.85	1.40	1.40	1.49	1.53	1.55	1.58
5	1.68	2.25	1.75	1.60	1.70	1.58	1.92	1.38	1.50	1.52	1.54	1.51

Mean daily gage height, in feet, of Niobrara River near Valentine, 1897–1906—Cont'd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.												
6	1.75	2.40	2.02	1.56	1.65	1.55	1.50	1.40	1.38	1.45	1.57	1.56
7	1.80	1.95	1.87	1.58	1.57	1.55	1.80	1.32	1.40	1.36	1.55	1.65
8	1.80	1.82	1.80	1.60	1.72	1.85	1.53	1.30	1.39	1.38	1.52	1.64
9	1.76	1.80	1.70	1.56	1.60	2.30	1.42	1.31	1.37	1.42	1.56	1.60
10	1.73	1.95	1.78	1.60	1.50	1.60	1.40	1.30	1.34	1.47	1.60	1.66
11	1.70	1.83	1.67	1.60	1.52	1.61	1.55	1.25	1.36	1.48	1.58	1.61
12	1.74	1.96	1.65	1.55	1.72	1.57	1.47	1.29	1.35	1.45	1.55	1.55
13	1.73	2.36	1.60	1.56	1.60	1.55	1.45	1.30	1.35	1.46	1.54	1.56
14	1.74	2.32	1.62	1.60	1.55	1.45	1.42	1.35	1.25	1.43	1.52	1.67
15	1.75	1.96	1.58	1.58	1.51	1.54	1.42	1.24	1.30	1.41	1.55	1.60
16	1.71	2.00	1.60	1.58	1.52	1.50	1.31	1.30	1.26	1.48	1.53	1.71
17	1.70	2.28	1.60	1.58	1.49	1.42	1.32	1.35	1.28	1.43	1.52	1.65
18	1.75	2.20	1.57	1.55	1.51	1.40	1.30	1.33	1.30	1.62	1.56	1.72
19	1.66	2.25	1.55	1.50	1.48	1.47	1.31	1.44	1.36	1.63	1.57	1.57
20	1.61	2.32	1.55	1.49	1.50	1.70	1.26	1.40	1.35	1.55	1.52	1.64
21	1.56	2.31	1.58	1.53	1.52	1.46	1.37	1.36	1.26	1.54	1.58	1.72
22	1.60	2.40	1.50	1.62	1.50	1.42	1.32	1.34	1.30	1.56	1.51	1.78
23	1.61	2.42	1.41	1.55	1.52	1.45	1.30	1.30	1.32	1.54	1.54	1.74
24	1.40	2.20	1.52	1.63	1.50	1.35	1.23	1.31	1.33	1.54	1.53	1.77
25	.95	2.15	1.53	1.60	1.51	1.51	1.32	1.27	1.36	1.53	1.48	1.72
26	1.45	2.20	1.39	1.58	1.45	1.41	1.27	1.25	1.35	1.51	1.54	1.10
27	1.72	2.23	1.52	1.61	1.47	1.35	1.34	1.26	1.37	1.50	1.53	1.40
28	2.15	2.32	1.58	1.50	1.45	1.36	1.37	1.35	1.42	1.55	1.60	1.85
29	2.25	2.15	1.60	1.57	1.45	1.38	1.30	1.35	1.40	1.57	1.54	1.75
30	2.20	.....	1.55	1.55	1.46	1.36	1.35	1.32	1.45	1.58	1.56	1.30
31	2.55	.....	1.62	.....	1.48	.....	1.32	1.34	.....	1.54	.....	2.20
1905.												
1	2.15	2.78	2.3	1.65	1.53	1.76	1.76	1.88	1.48	1.45	1.57	1.95
2	1.9	2.8	2.15	1.8	1.55	1.75	3.15	1.82	1.5	1.43	1.6	1.35
3	2.15	3.35	2.0	1.78	1.62	1.86	2.8	1.75	1.45	1.47	1.56	1.23
4	2.03	3.6	1.78	1.8	2.03	1.68	2.4	1.7	1.44	1.45	1.59	1.37
5	2.05	3.77	1.75	1.71	1.8	1.65	2.32	1.67	1.48	1.5	1.62	2.18
6	2.02	3.9	1.8	1.65	1.75	1.5	2.15	1.68	1.45	1.52	1.57	2.2
7	2.0	3.85	1.78	1.6	1.68	1.48	2.05	1.65	1.49	1.49	1.59	2.1
8	2.03	3.7	1.75	1.62	1.65	1.5	1.82	1.67	1.53	1.55	1.61	2.15
9	1.9	3.6	1.7	1.6	1.6	1.55	1.93	1.66	1.55	1.57	1.59	2.2
10	2.07	3.67	1.64	1.82	1.63	1.75	1.85	1.58	1.5	1.53	1.58	2.03
11	2.45	3.95	1.62	1.68	1.7	1.7	1.8	1.55	1.47	1.45	1.61	2.98
12	3.2	4.0	1.6	1.57	1.63	1.55	1.68	1.55	1.45	1.44	1.6	1.0
13	3.6	3.9	1.64	1.55	1.55	1.58	1.65	1.58	1.42	1.45	1.59	2.9
14	3.15	3.9	1.60	1.62	1.64	1.56	1.6	1.72	1.5	1.5	1.63	1.9
15	3.9	3.65	1.63	1.7	1.6	1.55	1.62	1.64	1.49	1.55	1.64	1.92
16	3.85	3.6	1.67	1.66	1.65	1.6	1.65	1.6	1.52	1.48	1.6	1.88
17	3.15	3.35	1.66	1.65	1.53	1.57	1.68	1.55	1.47	1.48	1.63	1.75
18	3.2	3.55	1.73	1.6	1.5	1.93	1.57	1.53	1.55	1.49	1.65	1.76
19	2.77	3.38	1.7	1.57	1.53	1.75	2.48	1.51	1.48	1.55	1.65	1.78
20	2.5	3.16	1.62	1.55	1.52	1.95	2.15	1.48	1.45	1.5	1.66	1.75
21	2.2	3.1	1.65	1.53	1.52	1.6	1.95	1.5	1.45	1.52	1.67	1.75
22	2.38	3.18	1.63	1.54	1.53	1.77	1.76	1.53	1.47	1.5	1.7	1.69
23	2.33	2.85	1.7	1.53	1.5	1.63	1.75	1.5	1.5	1.48	1.72	1.0
24	2.45	2.74	1.68	1.67	1.48	1.78	1.6	1.5	1.45	1.49	1.74	1.65
25	2.83	2.6	1.65	1.68	1.52	2.04	1.73	1.45	1.42	1.5	1.73	1.63
26	2.25	3.0	1.6	1.73	1.53	1.8	1.62	1.42	1.5	1.5	1.7	1.75
27	2.33	2.7	1.62	1.6	1.78	2.5	1.6	1.45	1.52	1.53	1.75	1.72
28	2.57	2.48	1.75	1.6	1.65	1.95	1.6	1.43	1.45	1.54	1.77	1.65
29	2.85	.....	1.65	1.55	2.2	1.72	1.61	1.49	1.5	1.58	1.56	1.58
30	1.9	.....	1.58	1.5	1.95	1.85	1.87	1.45	1.47	1.56	1.35	1.7
31	2.0	.....	1.61	.....	1.85	.....	1.8	1.48	.....	1.59	.....	1.56
1906.												
1	1.75	1.97	1.9	2.60	1.90	1.45	1.35	1.25	1.35	1.25	1.70	.....
2	1.70	1.92	.....	2.35	2.00	1.50	1.35	1.25	1.30	1.40	1.70	.....
3	1.76	1.95	.....	2.15	1.90	1.50	1.35	1.25	1.30	1.35	1.75	.....
4	1.80	1.90	2.55	2.12	1.90	1.60	1.35	1.60	1.25	1.30	1.75	.....
5	1.82	1.62	2.8	2.07	1.85	1.55	1.40	1.45	1.25	1.30	1.65	.....
6	1.85	1.5	2.55	1.96	1.90	1.55	1.35	1.50	1.25	1.25	1.68	.....
7	1.78	1.75	2.2	1.95	1.75	1.45	1.40	1.60	1.30	1.35	1.60	.....
8	1.55	1.83	2.5	2.10	1.65	1.40	1.30	1.50	1.30	1.35	1.60	.....
9	1.60	1.78	2.25	2.12	1.65	1.30	1.25	1.45	1.30	1.30	1.55	.....
10	1.68	1.85	2.05	2.07	1.60	1.30	1.30	1.55	1.25	1.30	1.55	.....

Mean daily gage height, in feet, of Niobrara River near Valentine, 1897–1906—Cont'd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906.												
11	1.63	1.87	1.75	1.98	1.65	1.45	1.55	1.50	1.55	1.25	1.50	.....
12	1.82	1.95	1.32	2.08	1.55	1.40	1.40	1.40	1.35	1.30	1.50	.....
13	1.93	1.75	1.35	2.30	1.60	1.35	1.35	1.45	1.35	1.35	1.55	.....
14	1.85	1.70	1.65	2.32	1.55	1.35	1.40	1.40	1.30	1.35	1.55	.....
15	1.87	1.75	1.6	2.07	1.55	1.40	1.40	1.35	1.40	1.40	1.60	.....
16	1.8	1.95	1.85	2.12	1.50	1.35	1.35	1.30	1.35	1.35	1.60	.....
17	1.85	2.08	1.9	2.05	1.55	1.40	1.35	1.30	1.30	1.45	1.45	.....
18	1.85	2.03	1.95	2.06	1.40	1.35	1.35	1.30	1.30	1.40	1.50	.....
19	1.90	2.15	1.95	2.02	1.40	1.40	1.30	1.25	1.40	1.40	1.40	.....
20	1.85	2.0	1.95	2.05	1.40	1.30	1.30	1.25	1.40	1.70	1.30	.....
21	1.65	1.95	2.12	1.90	1.45	1.30	1.30	1.30	1.45	1.60	1.45	.....
22	1.70	1.9	2.07	1.95	1.45	1.35	1.30	1.30	1.40	1.55	1.50	.....
23	2.45	2.0	2.0	1.95	1.50	1.35	1.30	1.50	1.30	1.50	1.55	.....
24	2.20	1.9	2.1	1.90	1.50	1.40	1.25	1.55	1.30	1.75	1.70	.....
25	2.20	1.85	2.0	1.85	1.55	1.40	1.25	1.50	1.40	1.50	1.65	.....
26	2.15	1.95	2.08	1.85	1.95	1.45	1.25	1.40	1.35	1.65	1.60	.....
27	2.18	1.85	2.15	1.80	1.60	1.45	1.30	1.30	1.30	1.70	1.55	.....
28	2.10	1.92	2.2	1.80	1.50	1.40	1.25	1.35	1.30	1.75	1.60	.....
29	2.10	.....	2.25	1.75	1.60	1.40	1.25	1.30	1.30	1.85	1.70	.....
30	2.05	.....	2.25	1.75	1.55	1.35	1.25	1.30	1.30	1.80	1.65	.....
31	1.95	.....	2.18	.....	1.50	.....	1.25	1.30	.....	1.70	.....	.....

Mean daily discharge, in second-feet, of Niobrara River near Valentine, 1901–1906.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Day.	July.	Aug.	Sept.	Oct.	Nov.
1901.						1901.					
1	865	805	805	655	805	17	525	580	700	700	930
2	620	655	750	700	750	18	525	580	620	750	930
3	620	655	700	750	700	19	655	555	655	805	930
4	580	655	1,080	700	700	20	620	555	655	805	1,000
5	580	580	865	655	805	21	555	655	620	750	930
6	580	580	655	700	750	22	525	620	700	750	1,000
7	555	580	4,330	750	750	23	525	580	620	700	930
8	555	555	1,155	805	750	24	510	655	700	750	930
9	655	580	930	930	805	25	555	620	700	700	930
10	580	620	805	1,330	750	26	580	700	620	750	930
11	620	655	865	1,000	1,000	27	655	655	700	700	930
12	580	555	865	1,000	1,000	28	620	655	750	700	930
13	525	580	805	930	930	29	580	655	700	750	1,000
14	525	655	865	805	805	30	620	655	655	750	1,000
15	525	580	750	750	1,000	31	580	700	.....	805	.....
16	525	620	750	805	1,000						

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	.....	.....	.....	865	930	750	4,260	580	655	700	865	805
2	.....	.....	.....	865	930	655	1,425	580	655	700	930	700
3	.....	.....	.....	930	865	700	1,075	655	580	655	805	805
4	.....	.....	.....	1,000	865	700	805	580	550	700	750	505
5	.....	.....	.....	1,000	930	805	865	655	580	700	805	655
6	.....	.....	.....	1,075	805	805	655	655	580	700	805	750
7	.....	.....	.....	750	700	700	550	580	550	700	805	750
8	.....	.....	.....	865	805	865	1,330	700	655	700	865	.....
9	.....	.....	.....	805	865	655	655	750	580	700	805	.....
10	.....	.....	1,155	805	805	655	580	655	550	750	750	.....
11	.....	.....	1,155	700	750	655	580	550	615	805	750	.....
12	.....	.....	1,075	805	930	750	615	525	580	805	805	.....
13	.....	.....	1,155	865	805	750	550	615	580	750	865	.....
14	.....	.....	930	865	805	655	580	655	615	750	865	.....
15	.....	.....	930	805	930	580	550	655	615	750	805	.....
16	.....	.....	655	930	700	655	550	655	615	805	865	.....
17	.....	.....	615	1,000	750	700	550	700	615	750	805	.....
18	.....	.....	865	930	750	615	655	615	700	750	865	.....
19	.....	.....	1,425	865	1,240	750	655	655	655	750	805	.....
20	.....	.....	1,240	805	1,155	700	655	615	750	750	805	.....

Mean daily discharge, in second-feet, of Niobrara River near Valentine, 1901–1906—Con.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
21	.....	.....	1,630	700	750	615	615	700	700	750	750	.....
22	.....	.....	970	1,075	700	580	580	700	700	750	805	.....
23	.....	.....	1,075	1,000	750	580	615	615	615	805	750	.....
24	.....	.....	1,525	750	700	615	655	700	615	750	805	.....
25	.....	.....	1,330	1,155	700	615	580	865	750	750	865	.....
26	.....	.....	1,425	1,075	655	615	655	700	865	805	750	.....
27	.....	.....	1,330	805	750	615	615	580	805	805	805	.....
28	.....	.....	1,330	1,000	615	700	580	655	700	750	805	.....
29	.....	.....	1,240	865	655	1,425	615	655	800	750	700	.....
30	.....	.....	1,425	930	615	1,740	700	700	655	805	750	.....
31	.....	.....	1,240	.....	655	.....	615	750	.....	750	.....	.....
1903.												
1	.....	.....	525	1,330	750	805	700	805	580	655	750	755
2	.....	.....	930	1,425	750	750	655	1,425	615	655	750	750
3	.....	.....	1,330	1,330	750	700	655	6,800	580	700	750	700
4	.....	.....	1,075	1,155	805	750	655	865	615	655	805	750
5	.....	.....	1,155	1,240	805	750	615	750	580	655	700	.....
6	.....	.....	1,155	930	805	700	655	550	580	655	750	700
7	.....	.....	1,330	930	865	700	615	550	615	655	750	750
8	.....	.....	1,425	930	865	750	615	550	615	580	750	655
9	.....	.....	1,525	1,000	865	805	615	525	580	615	750	750
10	.....	.....	1,740	1,240	1,000	700	615	525	580	615	750	655
11	.....	.....	1,630	1,000	1,075	700	655	550	580	700	750	655
12	.....	.....	1,860	865	865	615	655	580	580	750	805	655
13	.....	.....	1,860	865	865	615	615	580	615	655	865	580
14	.....	.....	1,740	865	805	615	700	655	615	700	805	525
15	.....	550	1,630	750	750	615	700	615	700	700	(a)	550
16	.....	525	1,525	805	750	615	655	655	700	750	(a)	655
17	.....	505	1,525	865	805	655	1,860	655	700	655	(a)	750
18	.....	805	1,630	1,000	805	615	7,000	615	655	655	(a)	750
19	.....	930	1,630	1,240	805	700	1,525	615	655	655	(a)	865
20	.....	1,075	1,155	1,155	750	655	805	615	700	655	(a)	750
21	.....	1,240	1,240	1,000	750	805	655	615	700	700	(a)	865
22	.....	1,425	1,000	930	750	655	615	615	750	750	750	750
23	.....	1,000	1,155	930	700	805	615	580	655	750	700	750
24	.....	1,240	1,075	805	700	700	580	580	655	700	615	750
25	.....	1,075	1,155	865	700	700	615	580	700	700	580	865
26	.....	1,525	1,425	750	865	655	615	615	655	655	655	1,000
27	.....	1,425	1,425	750	700	655	580	700	615	700	655	750
28	.....	655	1,330	865	700	700	550	615	615	750	700	700
29	.....	.....	1,330	805	805	655	580	615	655	750	615	700
30	.....	.....	1,240	750	700	615	615	550	700	700	655	655
31	.....	.....	1,330	.....	700	.....	700	580	.....	750	.....	700
1904.												
1	615	600	600	655	700	1,155	615	615	805	750	805	805
2	700	600	865	655	750	1,075	615	930	615	750	750	750
3	615	600	550	655	700	1,525	615	655	615	805	805	750
4	615	600	750	655	930	1,155	655	700	750	805	805	865
5	655	600	700	700	865	805	1,330	700	750	750	805	865
6	700	600	1,000	655	805	750	750	700	655	700	805	805
7	750	600	865	700	700	750	1,155	615	655	615	805	865
8	750	750	805	700	865	1,155	805	615	655	655	750	930
9	700	750	615	655	750	2,115	655	615	615	655	805	865
10	700	930	865	700	655	805	655	615	615	700	865	930
11	655	805	700	700	655	805	805	580	615	750	865	865
12	700	930	700	655	865	750	700	615	615	700	805	805
13	700	600	655	655	750	750	700	615	615	700	805	805
14	700	600	655	700	700	655	655	655	550	700	750	930
15	700	600	700	700	655	750	655	580	580	655	805	865
16	655	600	700	700	655	700	580	615	550	750	805	800
17	655	600	700	700	655	615	580	700	580	700	750	800
18	700	600	655	655	655	615	580	700	580	865	805	800
19	615	600	655	615	655	655	580	750	615	930	805	800
20	580	600	655	615	655	930	550	700	615	805	750	800
21	550	600	700	655	655	655	615	655	550	805	865	800
22	580	600	615	700	655	615	580	655	580	805	750	800
23	580	600	550	655	655	655	580	615	580	805	805	800
24	490	600	615	750	655	615	550	615	615	805	805	800
25	450	600	655	700	655	750	580	580	615	805	750	800

a Ice November 15 to 21.

Mean daily discharge, in second-feet, of Niobrara River near Valentine, 1901–1906—Con.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.												
26	505	600	550	700	655	655	580	580	615	750	805	800
27	655	600	615	700	655	615	655	580	615	750	805	800
28	600	600	700	615	655	615	655	615	655	805	865	800
29	600	600	700	655	655	655	615	615	655	805	805	800
30	600	.....	655	655	655	615	655	580	700	865	805	800
31	600	.....	700	.....	700	.....	615	615	.....	805	.....	800
1905.												
1	.....	.....	.....	905	740	1,005	1,065	1,375	760	725	820	.....
2	.....	.....	.....	1,125	760	990	3,420	1,270	785	705	855	.....
3	.....	.....	.....	1,095	835	1,160	2,845	1,150	730	745	805	.....
4	.....	.....	.....	1,125	1,480	895	2,165	1,070	720	725	835	.....
5	.....	.....	1,070	985	1,090	860	2,044	1,025	760	780	870	.....
6	.....	.....	1,150	900	1,015	695	1,755	1,040	730	800	810	.....
7	.....	.....	1,120	835	910	680	1,600	990	770	765	830	.....
8	.....	.....	1,070	860	870	700	1,210	1,015	815	835	850	.....
9	.....	.....	995	835	810	750	1,400	1,005	840	855	825	.....
10	.....	.....	910	1,150	845	1,005	1,280	990	780	810	815	.....
11	.....	.....	880	935	935	935	1,200	850	750	725	845	.....
12	.....	.....	860	795	845	750	1,020	850	730	715	830	.....
13	.....	.....	910	775	750	785	980	885	700	725	815	.....
14	.....	.....	860	855	855	765	915	1,085	780	775	865	.....
15	.....	.....	895	960	805	755	950	930	770	834	880	.....
16	.....	.....	950	905	865	815	1,000	905	805	750	825	.....
17	.....	.....	935	890	730	780	1,055	845	750	750	860	.....
18	.....	.....	1,035	825	700	1,310	900	820	840	760	880	.....
19	.....	.....	990	790	725	1,020	2,420	795	760	825	880	.....
20	.....	.....	880	770	715	1,345	1,855	765	725	765	890	.....
21	.....	.....	915	745	715	820	1,515	785	725	785	900	.....
22	.....	.....	890	755	725	1,055	1,190	820	750	760	940	.....
23	.....	.....	985	745	695	860	1,170	785	780	740	965	.....
24	.....	.....	955	910	675	1,075	940	785	725	750	995	.....
25	.....	.....	910	925	710	1,515	1,135	730	700	755	980	.....
26	.....	.....	845	995	720	1,110	965	700	780	755	935	.....
27	.....	.....	870	820	1,035	2,300	935	730	800	785	1,005	.....
28	.....	.....	1,055	820	855	1,365	935	710	725	795	1,030	.....
29	.....	.....	910	760	1,740	990	1,005	770	780	840	760	.....
30	.....	.....	820	710	1,310	1,200	1,365	730	745	815	575	.....
31	.....	.....	855	.....	1,140	.....	1,240	760	.....	845	.....	.....
1906.												
1	930	1,060	835	1,710	1,180	672	632	595	700	573	985	.....
2	875	1,000	1,080	1,350	1,300	720	632	595	660	685	985	.....
3	940	1,040	1,340	1,120	1,170	720	632	565	660	645	1,040	.....
4	985	985	1,590	1,080	1,160	815	632	907	625	608	1,040	.....
5	997	685	1,950	1,030	1,100	770	675	1,060	625	608	930	.....
6	1,040	595	1,590	905	1,140	770	635	810	625	573	980	.....
7	950	805	1,120	900	957	682	675	915	665	645	870	.....
8	705	890	1,520	1,070	840	645	600	810	665	645	870	.....
9	750	725	1,180	1,100	835	575	573	760	665	608	820	.....
10	828	890	940	1,050	780	577	607	865	625	608	820	.....
11	778	895	630	945	820	690	820	815	910	573	770	.....
12	970	985	390	1,060	725	648	685	720	710	608	770	.....
13	1,100	770	400	1,350	775	662	645	765	710	645	820	.....
14	1,000	725	562	1,370	730	616	685	725	670	645	820	.....
15	1,030	755	510	1,070	735	655	685	685	760	685	870	.....
16	930	965	680	1,130	690	620	645	642	715	645	870	.....
17	990	1,120	720	1,060	735	655	652	642	675	730	730	.....
18	990	1,060	790	1,070	655	620	652	647	675	685	770	.....
19	1,050	1,180	790	1,020	620	657	615	610	765	685	685	.....
20	978	995	800	1,060	620	585	615	610	765	985	607	.....
21	768	940	985	925	660	585	620	647	810	870	730	.....
22	815	885	945	1,000	660	620	620	650	685	820	770	.....
23	1,750	970	860	1,020	795	620	620	830	607	770	820	.....
24	1,400	860	995	990	705	662	585	880	607	1,040	985	.....
25	1,400	810	875	950	750	662	590	830	685	770	930	.....
26	1,330	915	990	980	1,200	705	590	740	645	930	870	.....
27	1,370	785	1,060	940	805	705	625	655	607	985	820	.....
28	1,240	855	1,140	960	710	666	590	695	607	1,040	870	.....
29	1,240	.....	1,200	930	810	666	595	655	607	1,160	985	.....
30	1,180	.....	1,220	960	760	630	595	660	607	1,100	930	.....
31	1,060	.....	1,130	.....	715	.....	595	660	.....	985	.....	.....

Estimated monthly discharge of Niobrara River near Valentine, 1901–1906.

[Drainage area, 6,070 square miles.]

Month and year.	Discharge in second-feet.			Total in acre-feet.	Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.	Per cent of rainfall.	
January.								
1904	750	450	634	39,000	0.104	0.12	20	0.60
1906	1,750	705	1,040	64,000	.171	.20	37	.54
February.								
1903 [a]	1,520	505	998	27,700				1.31
1904	930	600	640	36,800	.105	.11	46	.24
1906	1,180	595	898	49,900	.148	.15	34	.44
March.								
1902	1,630	615	1,169	71,900	.192	.22	12	1.84
1903	1,860	525	1,357	83,400	.224	.26	32	.81
1904	1,000	550	692	82,500	.144	.13	46	.28
1905	1,150	820	945	58,100	.156	.18	16	1.09
1906	1,950	390	994	61,200	.164	.19	12	1.55
April.								
1902	1,150	700	896	53,300	.148	.17	16	1.08
1903	1,425	750	979	58,200	.161	.18	10	1.72
1904	750	615	674	40,100	.111	.12	17	.70
1905	1,150	710	883	52,500	.145	.16	6	2.90
1906	1,710	900	1,070	63,700	.176	.20	10	2.10
May.								
1902	1,240	615	802	49,300	.132	.15	6	2.60
1903	1,070	700	794	48,800	.131	.15	5	3.27
1904	930	655	705	43,300	.116	.13	5	2.67
1905	1,740	675	890	54,700	.147	.17	3	5.24
1906	1,300	620	843	51,800	.139	.16	5	3.22
June.								
1901 [b]	700	620	659	6,500				7.02
1902	1,740	580	740	44,000	.122	.13	3	3.73
1903	805	615	692	41,200	.114	.13	8	1.66
1904	2,110	615	832	49,500	.137	.15	3	5.08
1905	2,300	680	1,010	60,100	.166	.18	3	5.79
1906	815	575	662	39,400	.109	.12	5	2.22
July.								
1901	865	510	585	36,000	.096	.11	7	1.49
1902	4,260	550	805	49,500	.133	.15	7	2.26
1903	7,000	550	912	56,100	.150	.17	3	5.74
1904	1,330	550	675	41,500	.111	.13	4	3.00
1905	3,420	900	1,402	86,200	.231	.27	6	4.51
1906	820	573	633	38,900	.104	.12	8	1.47
August.								
1901	805	555	624	38,400	.103	.12	5	2.44
1902	865	525	653	40,100	.106	.13	5	2.77
1903	6,800	525	843	51,800	.139	.16	6	2.81
1904	930	580	644	39,600	.106	.12	5	2.56
1905	1,370	700	902	55,500	.149	.17	10	1.69
1906	1,060	595	731	44.900	.120	.14	4	3.58
September.								
1901	4,330	620	879	52,300	.145	.16	5	3.38
1902	865	550	649	38,600	.107	.12	9	1.34
1903	750	580	638	38,000	.105	.12	8	1.52
1904	805	550	627	37,300	.103	.12	6	1.93
1905	840	700	760	45,200	.125	.14	14	.97
1906	910	607	678	40,300	.112	.12	4	3.02
October.								
1901	1,330	655	788	48,400	.130	.15	6	2.31
1902	805	655	745	45,800	.123	.14	17	.80
1903	750	580	685	42,100	.113	.13	21	.63
1904	930	615	760	46,700	.125	.14	11	1.28
1905	855	705	774	47,600	.128	.15	13	1.16
1906	1,160	573	760	46,700	.125	.13	4	2.99
November.								
1901	1,000	700	887	52,800	.146	.16	540	.03
1902	930	700	807	48,000	.133	.15	37	.41
1903	865	580	724	43,100	.119	.13	147	.09
1904	865	750	800	47,600	.132	.15	184	.08
1905	1,030	575	866	51,500	.143	.16	32	.50
1906	1,040	607	859	51,100	.142	.16	27	.60
December.								
1903	1,000	525	723	43,000	.119	.13	56	.23
1904	930	750	823	50,600	.136	.16	67	.24

[a] February 15 to 28.

[b] June 26 to 30.

NIOBRARA RIVER AT NIOBRARA.

A station was established May 11, 1902, near the mouth of Niobrara River, at a wooden highway bridge 1 mile southwest of the city of Niobrara, below all tributaries. It was abandoned October 25, 1902.

The river has here two channels about one-fourth mile apart. The bed of the stream is sandy and the cross section is continually changing. Velocities were high and accurate measurements could not be made.

The gage was of the wire and weight type, the length of the wire from the index to the end of the weight being 19 feet. The bench mark was the top of the face plate on the upstream pier at the left end of the bridge; elevation, 12.49 feet above the zero of the gage.

Discharge measurements of Niobrara River at Niobrara, 1902.

Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Second-feet.*
May 11	J. C. Stevens	2.55	1,637
July 6	do	2.85	2,021
July 25	do	2.00	1,401
August 21	do	2.10	1,106
September 28	do	1.90	2,201

Mean daily gage height, in feet, of Niobrara River at Niobrara, 1902.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Day.	May.	June.	July.	Aug.	Sept.	Oct.
1	.....	2.60	2.70	2.70	2.60	2.40	17	2.57	2.75	2.60	2.75	2.30	2.10
2	.....	2.50	2.90	2.65	2.50	2.40	18	2.67	2.70	2.60	2.80	2.20	1.90
3	.....	2.50	2.95	2.65	2.50	2.40	19	2.80	2.65	2.65	2.85	2.20	1.90
4	.....	2.55	2.90	2.60	2.50	2.30	20	2.90	2.65	2.60	2.75	2.50	2.00
5	.....	2.70	2.90	2.60	2.45	2.30	21	3.00	2.75	2.60	2.70	2.90	2.00
6	.....	2.60	2.80	2.55	2.45	2.30	22	2.90	2.80	2.60	2.80	2.80	1.90
7	.....	2.60	2.70	2.55	2.50	2.25	23	2.57	2.80	2.55	2.70	2.80	1.90
8	.....	2.55	2.70	2.55	2.45	2.20	24	2.45	2.60	2.60	2.60	2.60	1.90
9	.....	2.70	2.75	2.60	2.40	2.20	25	2.40	2.60	2.65	2.75	2.60	1.90
10	.....	2.60	2.67	2.60	2.45	2.20	26	2.50	2.70	2.75	2.90	2.50	.....
11	2.55	2.50	2.60	2.70	2.40	2.10	27	2.50	2.85	2.70	2.75	2.50	.....
12	2.57	2.75	2.60	2.60	2.35	2.10	28	2.60	2.70	2.70	2.65	2.50	.....
13	2.57	2.60	2.60	2.55	2.40	2.10	29	2.55	2.80	2.70	2.60	2.45	.....
14	2.70	2.60	2.65	2.50	2.35	2.10	30	2.50	2.75	2.70	2.55	2.40	.....
15	2.70	2.60	2.60	2.70	2.30	2.05	31	2.45	.....	2.70	2.60	.....	.....
16	2.75	2.65	2.60	2.70	2.20	2.00							

LAKES IN CHERRY AND ADJOINING COUNTIES.

Throughout the southern part of the Niobrara drainage basin, in Cherry, Brown, and Sheridan counties, are numerous lakes which form the headwaters of small tributary streams. The country in which they are found consists almost entirely of characteristic sand hills, and the lakes are simply water-filled depressions in the valleys, the bottoms of which are below the general level of the water table of the district. They range in size from small ponds to lakes several square miles in area and are generally shallow, with beds and banks

entirely of sand; in many of them rushes and aquatic plants grow thickly. In dry weather large quantities of wild hay are cut on the borders and even from the beds of the shallower lakes.

These lakes are subject to a periodic rise, beginning in April or May and due probably to the precipitation, which at certain seasons of the year is considerably greater than at others. In order to determine the extent of these fluctuations, their possible effects on the streams of which the lakes are the source, and the amount of "lag" between the rises and the seasons of heavier rainfall, a gaging station was maintained on Red Deer Lake, chosen as fairly representative of the type, from August 12, 1904, to October 31, 1905.

The lake is located in secs. 16, 17, 20, and 21, T. 30 N., R. 27 W., about 16 miles south of Woodlake post-office and about 30 miles south of Valentine.

The lake covers about 1 square mile of surface and is merely a valley or flat in the sand hills, filled with water. The depth varies from 1 foot to 15 feet, the average being probably about 8 feet. The bed is entirely of sand, and the margin is thickly grown with rushes and other aquatic plants.

The gage consists of a staff fastened to a post at the end of the boat landing 200 yards south of Cochran's ranch house near the east end of the lake. The bench mark is a group of three spikes driven horizontally near the base of a cottonwood tree 12 inches in diameter, located 40 feet south and 20 feet east of the southwest corner post of the large windmill tower just west of Cochran's house; elevation, 9.61 feet above the zero of the gage.

Weekly gage height, in feet, of Red Deer Lake near Woodlake, 1904–5.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.						1904.					
1						17		3.50			4.34
2		4.6				18					
3					4.32	19	4.5			4.33	
4				4.32		20					
5						21			4.35		
6						22					
7			4.33			23		4.31			
8						24					4.32
9						25				4.32	
10		4.42			4.34	26					
11						27	4.32				
12				4.33		28			4.32		
13						29					
14			4.31			30		4.36			4.38
15						31					
16											

Weekly gage height, in feet, of Red Deer Lake near Woodlake, 1904–5—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1905.										
1				4.39			4.75			
2									4.3	
3		4.46	4.36			4.55				
5					4.49			4.71		
6	4.4									
7				4.43						4.16
8							4.82			
9									4.32	
10			4.29			4.62				
11		4.5								
12								4.59		
13					4.52					
14	4.41						4.72			4.23
15				4.4						
16									4.3	
17		4.49	4.35			4.6				
19								4.5		
20	4.4				4.41					
21				4.36						
22							4.68			4.24
23									4.3	
24						4.7				
25		4.44	4.3							
26								4.4		
27					4.52					
28	4.41									
29				4.4			4.65			4.3
30									4.2	

MISCELLANEOUS MEASUREMENTS IN THE NIOBRARA BASIN.

The following discharge measurements have been made in the Niobrara basin at points other than the regular gaging stations in Nebraska:

Miscellaneous discharge measurements in Niobrara River basin, 1896–1905.

Stream.	Locality.	Date.	Hydrographer.	Discharge.
				Sec.-feet.
Antelope Creek	Sec. 12, T. 32 N., R. 40 W.	June 2, 1898	A. B. McCoskey	3.1
Ash Creek	Sec. 10, T. 31 N., R. 17 W.[a]	June 20, 1898	C. B. Channel	2.2
Baker Creek	N. line Sec. 19, T. 31 N., R. 13 W.	June 19, 1899	do	.4
Bear Creek	Sec. 31, T. 34 N., R. 34 W.	Aug. 19, 1904	J. C. Stevens	2
Beaver Creek	Ravenna	Mar. 11, 1903	do	984
Do	Sec. 19, T. 32 N., R. 16 W.	Apr. 27, 1905		20
Boardman Creek	Sec. 13, T. 30 N., R. 31 W.	July 24, 1897	O. V. P. Stout	[b] 1
Do	Sec. 6, T. 29 N., R. 33 W.	May 20, 1898	A. B. McCoskey	[b] 40
Do	Sec. 13, T. 30 N., R. 31 W.	June 3, 1899	C. B. Channel	16.4
Do	Sec. 1, T. 30 N., R. 31 W.	Aug. 16, 1904	J. C. Stevens	7.3
Bone Creek	Ainsworth	June 12, 1898	C. B. Channel	3.9
Do	Long Pine	Sept. 8, 1898		13.8
Do	do	Sept. 10, 1898	Glenn E. Smith	14
Do	Sec. 16, T. 31 N., R. 21 W.	June 17, 1899	C. B. Channel	12.5
Buck Creek	Sec. 14, T. 31 N., R. 41 W.	Sept. 1, 1898	A. B. McCoskey	[b] 4
Burton Creek	Sec. 28, T. 35 N., R. 19 W.	Sept. 17, 1898	C. B. Channel	5.5
Bush Creek	Sec. 23, T. 33 N., R. 13 W.	Aug. 14, 1902	P. T. Francis	25
Cedar Creek	Sec. 33, T. 34 N., R. 25 W.[c]	July 9, 1899	C. B. Channel	7.4
Cottonwood Creek, Big.	Sec. 21, T. 35 N., R. 22 W.	June 12, 1899	do	1.2
Crooked Creek	Sec. 20, T. 34 N., R. 19 W.	June 18, 1898	do	.7
Do	Sec. 19, T. 34 N., R. 19 W.	June 13, 1899	do	1.2
Deer Creek	Sec. 22, T. 30 N., R. 43 W.	June 1, 1898	A. B. McCoskey	12
Do	Sec. 55, T. 30 N., R. 43 W.	Aug. 23, 1904	J. C. Stevens	7.3
Eagle Creek, North Fork.	Sec. 26, T. 31 N., R. 13 W.	Apr. 26, 1905		8.1
Eagle Creek, South Fork.	Sec. 9, T. 30 N., R. 13 W.	do		25

[a] Above Spragg's dam. [b] Estimated. [c] At Bruce's mill.

Miscellaneous discharge measurements in Niobrara River basin, 1896–1905—Continued.

Stream.	Locality.	Date.	Hydrographer.	Discharge.
				Sec.-feet.
Elk Creek	Bassett	Sept. 9, 1898	Glenn E. Smith	2
Fairfield Creek	Sec. 31, T. 33 N., R. 23 W.	June 11, 1898	C. B. Channel	23.5
Do	do	Aug. 13, 1904	J. C. Stevens	21.5
Gordon Creek	Sec. 15, T. 32 N., R. 29 W.	July 23, 1897	O. V. P. Stout	3.5
Holt Creek	Sec. 19, T. 35 N., R. 20 W.[a]	June 12, 1899	C. B. Channel	3.6
Horsehead Creek	Sec. 16, T. 33 N., R. 24 W.	June 9, 1899	do	1.2
Keyapaha River	Sec. 28, T. 35 N., R. 19 W.[b]	June 17, 1898	do	62
Do	Sec. 24, T. 35 N., R. 20 W.	June 13, 1899	do	39
Do	Butte	July 13, 1904	J. C. Stevens	204
Do	Sec. 24, T. 34 N., R. 16 W.	Oct. 23, 1904	Adna Dobson	78
Do	Butte	July 18, 1905		136
Long Pine Creek	Long Pine	Oct. 3, 1896	Adna Dobson	47.1
Do	do	June 20, 1898	C. B. Channel	50.4
Do	do	Aug. 21, 1898	Glenn E. Smith	44.3
Do	do	Sept. 8, 1898	do	138
Do	do	Aug. 9, 1902	B. E. Forbes	49.7
Do	do	Oct. 6, 1903	Adna Dobson	38.7
Do	do	do	do	55
Do	Sec. 5, T. 31 N., R. 20 W.[c]	June 15, 1899	C. B. Channel	5.9
Middle Creek, East	Sec. 32, T. 33 N., R. 23 W.	June 10, 1899	do	.3
Middle Creek, West	do	do	do	1.5
Mill race	Butte[d]	July 13, 1904	J. C. Stevens	53
Minnechaduza Creek	Fort Niobrara	May 26, 1896	Adna Dobson	[e] 4.5
Do	do	Oct. 4, 1896		[e] 45.2
Do	Valentine	June 24, 1897	O. V. P. Stout	[f] 21.2
Do	do	May 13, 1898	Glenn E. Smith	[f] 23.2
Do	do	May 18, 1898	A. B. McCoskey	[f] 106
Do	do	May 24, 1898	Glenn E. Smith	[f] 90
Do	do	June 6, 1898	C. B. Channel	[f] 33.9
Do	do	June 12, 1898	Glenn E. Smith	[f] 52
Do	do	July 27, 1898	do	[f] 15.3
Do	do	Aug. 21, 1898	do	[f] 18.2
Do	do	Sept. 7, 1898	do	[f] 18.8
Do	do	Sept. 27, 1898	do	[f] 22.1
Do	do	Oct. 15, 1898	do	[f] 22.5
Do	do	Oct. 29, 1898	do	[f] 27
Do	do	Nov. 17, 1898	do	[f] 21
Do	do	Dec. 17, 1898	do	[f] 23
Do	do	Dec. 28, 1898	do	[f] 39
Do	do	Jan. 27, 1899	do	[f] 26.2
Do	do	Feb. 21, 1899	do	[f] 45
Do	do	Mar. 15, 1899	do	[f] 25.7
Do	do	Apr. 26, 1899	do	[f] 32.6
Do	do	May 11, 1899	do	[f] 35
Do	do	May 26, 1899	do	[f] 65
Do	do	June 26, 1899	do	[f] 23
Do	do	Aug. 13, 1899	do	[f] 19
Do	do	Sept. 13, 1899	do	[f] 23.5
Do	do	Sept. 26, 1899	do	[f] 26.5
Do	do	Aug. 1, 1901	O. V. P. Stout	[f] 27.3
Do	do	Nov. 14, 1901	B. E. Forbes	[f] 26.6
Do	do	Mar. 22, 1902	J. C. Stevens	[f] 38.1
Do	do	Apr. 12, 1902	do	[f] 38.3
Do	do	June 5, 1902	do	[f] 23.1
Do	do	July 4, 1902	do	[f] 27.4
Do	do	July 20, 1902	do	[f] 22.7
Do	do	Aug. 20, 1902	do	[f] 23.8
Do	do	Aug. 25, 1903	do	[f] 27
Do	do	May 26, 1903	do	[f] 33.1
Do	do	Apr. 26, 1903	do	[f] 47.6
Do	do	Aug. 24, 1904	do	[f] 21
Do	Sec. 29, T. 35, N., R. 30 W.	Apr. 11, 1902	do	14.9
Do	Sec. 2, T. 34 N., R. 30 W.	do	do	17.3
Do	Sec. 8, T. 34 N., R. 29 W.	do	do	26
Do	Sec. 30, T. 34 N., R. 28 W.	do	do	33.8
Newman Creek	Sec. 17, T. 33 N., R. 24 W.[g]	June 9, 1899	C. B. Channel	.7
Niobrara River	Marsland	June 23, 1896	E. T. Youngfelt	4
Do	do.[h]	Oct. 31, 1898	Glenn E. Smith	23.2
Do	do	May 29, 1899	C. B. Channel	36.2
Do	do.[h]	Sept. 7, 1900	T. J. O'Keefe	11.2
Do	Valentine	Oct. 4, 1896	Adna Dobson	71.2
Do	Niobrara	June 22, 1897	O. V. P. Stout	759
Do	do	Apr. 6, 1901	do	1,591
Do	do	Apr. 7, 1901	do	2,115
Do	do	Aug. 27, 1901	do	990
Do	do	May 11, 1902	J. C. Stevens	1,637
Do	do	July 6, 1902	do	2,021

[a] Head of Webster ditch.
[b] At mouth Burton Creek.
[c] Below Miller's mill.
[d] Electric power plant.
[e] Below dam and power house.
[f] Above backwater from dam.
[g] Head of Newman ditch.
[h] At Gregg's bridge.

Miscellaneous discharge measurements in Niobrara River basin, 1896–1905—Continued.

Stream.	Locality.	Date.	Hydrographer.	Discharge.
				Sec.-feet.
Niobrara River	Niobrara City	July 25, 1902	J. C. Stevens	1,401
Do	do	Aug. 21, 1902	do	1,106
Do	do	Sept. 28, 1902	do	2,201
Do	Belle	Oct. 23, 1897	A. B. McCoskey	11.9
Do	Lavaca	June 25, 1897	O. V. P. Stout	105
Do	do	Apr. 26, 1898	Glenn E. Smith	210
Do	do	June 2, 1898	A. B. McCoskey	152
Do	do	Oct. 30, 1898	Glenn E. Smith	203
Do	Dunlap	May 30, 1898	A. B. McCoskey	75
Do	do	Aug. 7, 1900	do	14.1
Do	Butte	July 13, 1904	J. C. Stevens	2,808
Do	Fort Niobrara	Mar. 22, 1902	do	1,226
Do	do	Apr. 12, 1902	do	877
Do	do	June 15, 1902	do	588
Do	do	July 4, 1902	do	714
Do	do	July 20, 1902	do	705
Do	Nebr.–Wyo. state line	Oct. 20, 1897	A. B. McCoskey	3.5
Do	Dawes County	May 4, 1887		98
Do	Sec. 23, T. 29 N., R. 56 W.	Oct. 21, 1897	A. B. McCoskey	16.3
Do	Sec. 31, T. 29 N., R. 56 W.	Oct. 22, 1897	do	9.2
Do	O. Harris's, T. 28 N., R. 54 W.	Oct. 23, 1897	do	13.4
Do	Sec. 11, T. 28 N., R. 53 W.	Oct. 25, 1897	do	17.1
Do	do	Sept. 6, 1900	T. J. O'Keefe	10.8
Do	Sec. 10, T. 28 N., R. 52 W.	Oct. 25, 1897	A. B. McCoskey	16.8
Do	Sec. 13, T. 31 N., R. 41 W.	Apr. 26, 1897	Engineers Golden Irrigation district.	190
Do	do	Apr. 27, 1897	do	195
Do	Sec. 27, T. 30 N., R. 57 W. [a]	Oct. 20, 1897	A. B. McCoskey	5.1
Do	Sec. 33, T. 30 N., R. 56 W. [b]	Oct. 21, 1897	do	6.3
Do	Sec. 9, T. 29 N., R. 56 W. [c]	do	do	7.3
Do	Sec. 22, T. 29 N., R. 48 W.	May 31, 1898	do	56
Do	Sec. 11, T. 32 N., R. 22 W.	June 13, 1898	C. B. Channel	959
Do	Sec. 25, T. 29 N., R. 50 W. [d]	May 29, 1898	do	47.9
Do	Sec. 12, T. 28 N., R. 54 W.	May 28, 1899	do	33
Do	Sec. 6, T. 28 N., R. 55 W.	Aug. 3, 1899	A. B. McCoskey	13.9
Do	do	Aug. 16, 1899	do	10.6
Do	Sec. 19, T. 33 N., R. 27 W.	Mar. 5, 1899	Glenn E. Smith	650
Do	Sec. 32, T. 30 N., R. 56 W.	May 27, 1899	C. B. Channel	13.6
Do	Sec. 26, T. 29 N., R. 41 W. [e]	Aug. 7, 1900	A. B. McCoskey	14.5
Do	Sec. 29, T. 29 N., R. 47 W. [f]	do	do	4
Do	Sec. 6, T. 28 N., R. 51 W.	July 18, 1900	do	7
Do	W. line sec. 26, T. 29 N., R. 46 W.	June 3, 1902	Adna Dobson	25.4
Do	Sec. 31, T. 33 N., R. 23 W.	Aug. 13, 1904	J. C. Stevens	752
Do	Sec. 26, T. 34 N., R. 26 W.	Aug. 14, 1904	do	679
Do	Sec. 10, T. 33 N., R. 34 W.	Aug. 18, 1904	do	221
Do	Sec. 11, T. 33 N., R. 36 W.	Aug. 20, 1904	do	200
Do	Sec. 27, T. 33 N., R. 37 W.	do	do	180
Do	Sec. 34, T. 33 N., R. 38 W.	Aug. 21, 1904	do	117
Do	Sec. 24, T. 31 N., R. 42 W.	Aug. 22, 1904	do	54
Do	Sec. 18, T. 30 N., R. 43 W.	Aug. 23, 1904	do	27
Pine Creek	Sec. 35, T. 30 N., R. 44 W.	Oct. 1, 1898	A. B. McCoskey	24.5
Do	Sec. 22, T. 30 N., R. 44 W.	Aug. 23, 1904	J. C. Stevens	12.8
Plum Creek	Sec. 13, T. 32 N., R. 22 W. [g]	June 13, 1898	C. B. Channel	101
Do	Johnstown	Sept. 8, 1898	Glenn E. Smith	10
Do	Sec. 35, T. 32 N., R. 23 W.	June 10, 1899	C. B. Channel	81
Do	Sec. 27, T. 31 N., R. 24 W. [h]	Oct. 26, 1900	A. B. McCoskey	28.8
Do	Sec. 7, T. 31 N., R. 23 W.	Aug. 13, 1904	J. C. Stevens	80
Pole Creek	Sec. 28, T. 32 N., R. 40 W.	Oct. 2, 1898	A. B. McCoskey	[i] 2
Rock Spring Creek	Sec. 12, T. 32 N., R. 22 W. [j]	June 14, 1898	C. B. Channel	2.3
Rock Creek	Sec. 4, T. 31 N., R. 18 W.	June 20, 1898	do	2.1
Do	Sec. 28, T. 32 N., R. 18 W.	do	do	4.4
Rush Creek	Sec. 32, T. 31 N. R. 42 W.	Aug. 22, 1904	J. C. Stevens	.6
Sandy Creek	Sec. 3, T. 31 N., R. 15 W.	June 17, 1899	C. B. Channel	8.3
Shobe Branch	Sec. 32, T. 33 N., R. 11 W.	June 20, 1899	do	1.7
Snake River	Sec. 30, T. 31 N., R. 30 W.	Mar. 16, 1897	Engineers Golden Irrigation district.	222
Do	Sec. 2, T. 30 N., R. 31 W.	Mar. 22, 1897	do	250
Do	do	Apr. 13, 1897	do	225
Do	Sec. 30, T. 31 N., R. 30 W.	do	do	240
Do	Sec. 2, T. 32 N., R. 30 W. [g]	July 23, 1897	O. V. P. Stout	280
Do	Sec. 1, T. 30 N., R. 31 W. [k]	July 24, 1897	do	215
Do	Sec. 15, T. 32 N., R. 30 W.	Aug. 16, 1904	J. C. Stevens	279
Do	Sec. 10, T. 30 N., R. 31 W.	do	do	204
Do	Sec. 2, T. 30 N., R. 32 W.	Aug. 17, 1904	do	194
Do	Sec. 16, T. 31 N., R. 30 W.	Oct. 27, 1904	do	245

[a] Above Warneke's ditch.
[b] Above Baurrett's ditch.
[c] Above Earnest dam.
[d] Head of Hatch & Cross ditch.
[e] Head of Mirage canal.
[f] Head of Hay Spring canal.
[g] At mouth.
[h] Hoef's mill.
[i] Estimated.
[j] Above Moore's ditch.
[k] At mouth Boardman Creek.

Miscellaneous discharge measurements in Niobrara River basin, 1896–1905—Continued.

Stream.	Locality.	Date.	Hydrographer.	Discharge.
				Sec.-feet.
Spring Creek	Mills	June 16, 1898	C. B. Channel	7.3
Do	Sec. 35, T. 34 N., R. 19 W.[a]	June 13, 1899	do	5.2
Do	Sec. 29, T. 32 N., R. 20 W.[b]	June 15, 1899	do	.3
Verdigris Creek	Sec. 6, T. 31 N., R. 6 W.[c]	Apr. 7, 1901	O. V. P. Stout	105
West Middle Creek	Sec. 29, T. 33 N., R. 23 W.[d]	June 11, 1898	H. O. Smith	1.8
Do	NE ¼ NW ¼ Sec. 29, T. 33 N., R. 23 W.	do	do	.9
White Clay Creek	Sec. 2, T. 33 N., R. 45, W.	May 20, 1899	do	5.3
Do	Sec. 36, T. 35 N., R. 45, W.	June 19, 1904	G. W. Bates	11
Wooden Spring Branch	Sec. 25, T. 35 N., R. 29, W.	June 13, 1899	C. B. Channel	2.1

[a] Head Townsend ditch. [b] Head Opperman ditch. [c] At mouth. [d] Above Allen's ditch.

PRECIPITATION IN THE NIOBRARA BASIN.

The following is a list of the precipitation stations in the drainage basin of Niobrara River:

Rainfall stations in Niobrara basin.

Station.	County.	Latitude.	Longitude.	Elevation.	Length of record.
		° ′	° ′		*Years.*
Santee	Knox	42 29	97 43		19
Lynch	Boyd	42 51	98 24		14
Agee	Holt	42 37	98 34		15
Kirkwood	Rock	42 43	99 18		11
Springview	Keyapaha	42 49	99 45		16
Valentine	Cherry	42 50	100 32	2,598	18
Kennedy	do	42 30	100 53	2,700	16
Hay Springs	Sheridan	42 40	102 38	3,821	19
Fort Robinson	Dawes	42 39	103 24	3,764	22

The subjoined table shows the precipitation at the stations named in the foregoing list:

Precipitation at stations in drainage basin of Niobrara River, 1896–1906.

SANTEE, KNOX COUNTY.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.55	0.68	1.17	2.74	3.43	4.00	3.46	2.86	2.29	1.83	0.80	0.56	24.37
1896	.07	.11	1.23	5.59	4.21	4.25	3.97	1.76	2.40	3.31	2.00	.05	28.95
1897	1.37	.44	1.33	4.32	.86	2.19	2.71	1.28	1.66	2.09	.52	1.43	20.20
1898	.66	.99	.60	1.10	4.56	2.41	6.16	2.47	.82	3.83	.32	.27	24.19
1899	.16	.95	1.16	2.31	2.47	3.97	2.56	4.80	T.	.49	1.21	.78	20.86
1900	T.	.59	1.60	4.42	2.76	1.30	7.72	1.72	2.44	3.15	.24	.05	25.99
1901	.08	.61	.62	1.77	2.19	9.09	.52	2.44	7.04	1.66	.82	1.13	27.97
1902	.73	.67	1.18	.86	1.35	6.31	5.31	5.73	5.94	.48	.20	2.14	30.90
1903	.12	1.74	1.10	1.26	9.70	2.80	5.26	4.52	1.26	1.68	.89	.19	30.52
1904	.56	.34	.50	2.63	3.71	3.77	3.86	5.05	.76	4.26	.38	.65	26.47
1905	.86	.25	3.34	1.91	4.65	4.71	5.40	4.70	5.36	1.83	2.00	.00	35.01
1906	.60	.64	1.29	2.99	3.53	3.41	2.39	4.60	3.00	4.61	1.19	1.17	29.42

Precipitation at stations in drainage basin of Niobrara River, 1896–1906—Continued.

LYNCH, BOYD COUNTY.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.28	0.54	1.04	3.09	2.88	3.67	4.02	3.14	2.10	1.18	0.59	0.48	23.01
1896	.16	.03	1.13	6.45	1.89	5.86	4.76	1.25	2.17	1.93	1.47	.05	27.15
1897	.74	.48	1.73	5.90	1.34	3.09	3.51	1.31	2.25	2.58	.57	1.10	24.60
1898	.36	.60	.52	1.61	6.05	1.91	4.85	2.03	.67	.79	.08	.07	19.54
1899	.16	.38	.59	1.54	3.96	3.23	3.37	9.25	.17	.76	1.18	.14	24.73
1900	T.	.25	.77	4.41	2.00	1.18	6.53	3.39	2.85	2.10	.10	.26	23.84
1901	.13	.60	.97	1.33	2.16	10.64	2.01	3.21	4.86	.90	.41	.60	27.82
1902	.50	.80	1.79	1.82	1.57	1.71	4.36	6.50	2.98	.32	.11	1.99	24.45
1903	.13	1.84	.70	1.20	7.25	3.11	7.31	3.67	1.96	1.27	1.04	.30	29.78
1904	.53	.50	.48	1.57	3.11	5.46	5.04	1.15	1.36	3.40	.00	.....	.....
1905	1.30	.16	2.80	2.56	5.79	4.57	3.23	2.06	1.92	2.09	1.89	.00	28.37
1906	.60	.....	1.70	3.76	2.28	.80	1.48	2.92	3.34	4.04	.70	.34	.....

AGEE, HOLT COUNTY.

Normal	0.45	0.65	1.05	3.08	3.13	4.18	3.05	2.99	2.33	1.60	0.67	0.74	23.92
1896	.11	.11	1.03	5.50	1.35	4.35	6.33	1.12	2.73	2.27	2.00	T.	26.90
1897	1.37	1.16	1.34	4.08	2.31	3.94	1.74	.43	2.68	2.88	.22	2.15	24.30
1898	.65	.63	.41	1.99	5.46	2.51	3.05	2.72	1.47	2.06	.53	.35	21.83
1899	.27	.13	1.02	1.50	3.00	4.40	4.32	6.95	.10	.59	1.10	.10	23.48
1900	.04	1.04	.93	5.90	.....	.....	6.96	2.69	2.76	3.95	.18	.17	.....
1901	.11	.45	.89	1.86	2.05	13.27	1.15	2.17	5.75	1.70	.88	.91	31.19
1902	.75	.68	2.03	1.37	1.60	3.32	3.31	8.67	6.92	.99	.15	3.95	33.74
1903	.15	.95	.50	1.31	7.38	1.63	4.82	2.65	1.13	1.30	.77	.40	22.99
1904	.59	.54	.13	1.57	2.73	.....	.....	.....	1.26	3.47	.30	.49	.....
1905	1.47	.57	3.69	2.62	8.30	3.58	3.51	.....	.....	2.21	1.95	T.	.....
1906	.67	.10	1.55	4.30	.....	.78	.54	.....	3.97	.....	.....	.....	.....

KIRKWOOD, ROCK COUNTY.

Normal	0.58	0.59	1.10	2.49	4.04	3.62	3.89	3.76	2.34	2.02	0.64	0.59	25.66
1896	.50	.05	2.25	3.62	.56	5.24	3.08	1.02	3.24	1.49	1.50	.08	22.63
1897	.90	.92	.99	2.69	1.50	4.33	3.33	1.41	1.60	4.68	.52	1.07	23.94
1898	.60	.74	.72	1.52	6.26	3.30	4.31	1.87	.49	.19	.35	.24	20.59
1899	.42	.44	.88	.71	3.63	3.19	4.10	6.58	.30	1.69	.67	.15	22.76
1900	T.	.75	.58	5.35	1.97	3.35	6.78	3.17	.72	3.93	.10	.33	27.03
1901	.17	.95	1.02	2.54	.98	11.20	.97	2.24	6.68	2.00	.59	1.17	30.51
1902	.60	.32	.60	1.27	2.69	1.65	3.11	8.74	4.64	.66	.36	2.70	27.34
1903	.18	1.00	.67	2.01	6.66	2.44	9.15	3.66	1.49	1.17	.35	.12	28.93
1904	.71	.48	.20	1.14	3.10	4.23	4.70	5.29	1.42	2.22	.10	.15	23.74
1905	1.20	.50	2.49	2.08	4.48	6.49	2.03	1.93	2.03	2.01	.93	.00	26.17
1906	1.05	.35	1.65	4.42	2.44	1.97	1.20	5.46	3.08	2.22	1.00	1.05	25.89

SPRINGVIEW, KEYAPAHA COUNTY.

Normal	0.49	0.50	0.98	2.68	2.82	3.69	2.84	2.98	1.55	1.19	0.41	0.65	20.7
1896	.25	.04	1.01	4.47	.92	6.05	3.41	1.27	2.10	1.12	.92	T.	21.56
1897	1.15	.39	.50	1.31	2.11	1.90	1.12	2.14	2.01	2.75	.30	.....	.....
1898	.15	.12	.32	.70	5.85	2.90	2.14	1.91	.52	.....	.30	1.00	.....
1899	.95	.25	.81	.96	4.21	2.84	2.61	3.68	.30	.09	.30	.....	.....
1900	.....	.20	.20	5.45	2.71	2.37	7.34	4.63	.28	.85	T.	T.	.....
1901	.10	1.10	1.19	2.56	1.69	8.84	.92	2.72	5.21	1.72	T.	.90	26.95
1902	.....	.....	.....	1.20	2.64	1.40	2.00	5.45	1.99	.52	.....	3.60	.....
1903	.20	1.50	.44	1.55	3.68	1.68	6.33	4.02	2.93	.52	.05	.05	22.95
1904	.40	.25	.21	1.20	1.64	4.25	5.54	2.12	1.10	1.91	T.	.15	18.77
1905	1.40	.....	1.32	1.69	4.43	8.85	3.53	1.37	1.32	1.81	.45	.00	.....
1906	.40	.....	1.95	3.80	2.21	1.23	.37	6.38	3.24	2.86	.25	.....	.....

Precipitation at stations in drainage basin of Niobrara River, 1896–1906—Continued.

VALENTINE, CHERRY COUNTY.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Normal	0.60	0.74	1.49	2.84	2.82	3.45	2.50	2.05	0.98	0.90	0.41	0.37	19.15
1896	.....	.....	1.81	3.06	.67	4.48	4.25	.77	2.73	.35	2.57	.40	.....
1897	1.22	1.94	1.50	2.19	3.71	1.69	4.71	2.09	.67	2.01	.93	1.06	23.69
1898	.44	.28	.57	1.33	5.98	2.11	2.28	3.62	.64	.09	.54	.37	18.25
1899	.47	.45	1.28	.74	2.84	2.69	1.34	2.59	.10	.98	.14	.40	14.02
1900	.04	.26	.47	4.70	1.23	1.24	7.97	4.67	.86	.38	.26	.15	22.23
1901	.04	1.19	1.70	1.46	.90	7.85	2.38	2.49	4.06	1.79	.05	.93	24.84
1902	.34	.20	1.07	.77	2.17	1.89	1.79	2.93	.25	.39	.53	1.28	13.61
1903	.22	.73	.28	1.81	2.41	1.43	3.95	4.21	1.70	.22	.04	.15	17.15
1904	.53	.22	.64	.40	2.93	4.67	6.08	3.08	1.17	.54	.19	.16	20.61
1905	1.01	.51	1.18	2.77	5.12	8.18	4.31	.85	1.45	1.61	1.35	.03	28.37
1906	.52	.33	2.50	2.68	4.14	1.56	1.88	5.02	3.17	3.42	.92	.40	26.54

KENNEDY, CHERRY COUNTY.

Normal	0.69	0.78	1.49	2.49	3.10	4.42	3.47	2.63	1.42	1.04	0.56	0.69	22.98
1896	.28	T.	1.95	2.82	1.31	3.91	4.89	.25	2.76	1.45	1.01	.30	20.93
1897	1.00	.36	1.63	1.80	1.76	3.80	3.63	3.61	.63	1.49	1.74	2.40	23.85
1898	1.52	T.	.64	1.38	8.63	1.91	3.70	2.31	.71	.30	.70	.40	22.20
1899	.55	.75	2.27	.41	1.73	3.47	3.18	5.19	.00	.30	.12	.88	18.85
1900	.15	1.08	.72	4.35	3.80	2.25	9.90	4.28	.38	.87	.20	.55	28.53
1901	T.	1.15	1.45	2.94	1.57	10.45	.39	2.80	6.99	.....	.....	.....	.....
1902	.60	.....	1.27	.88	3.65	4.04	3.66	4.66	1.89	1.39	.70	2.80	.....
1903	.70	2.72	.30	1.65	4.48	2.35	5.38	2.29	1.30	.48	T.	.40	22.05
1904	1.20	.15	.26	.15	3.56	7.58	2.84	3.03	1.92	.94	.05	.25	21.93
1905	1.83	.40	1.44	3.36	5.30	7.52	7.58	2.11	.85	.80	.....	.00	.....
1906	1.30	.25	2.50	2.75	3.32	.79	2.35	4.82	3.21	3.35	.95	1.40	26.99

HAY SPRINGS, SHERIDAN COUNTY.

Normal	0.70	0.73	1.58	2.18	3.21	3.25	2.71	1.94	1.07	1.26	0.60	0.73	19.95
1896	.49	.81	2.30	3.22	1.79	4.85	1.64	.86	1.73	.80	1.37	.....	.....
1897	2.45	.50	2.68	1.65	2.27	1.52	3.62	3.10	.18	1.20	1.60	1.12	21.89
1898	.40	.55	.88	1.11	6.91	.43	2.74	.31	1.31	.25	.48	.62	15.99
1899	.41	.50	2.94	1.56	2.82	1.97	1.60	1.47	.41	.78	.53	.85	15.84
1900	.29	.20	.59	3.91	.59	3.82	3.19	1.22	2.39	1.22	T.	.65	18.07
1901	T.	.92	2.09	2.90	3.99	5.13	1.66	3.30	.85	3.04	T.	.98	24.86
1902	.20	2.01	3.09	1.26	2.00	5.25	1.71	1.98	1.62	.78	.15	1.98	22.03
1903	.48	1.20	.92	2.19	3.91	2.16	8.92	2.22	1.92	.98	.21	T.	25.11
1904	.49	.13	.12	.85	2.26	3.68	2.16	1.92	3.14	3.17	.....	.....	.....
1905	1.00	.35	2.56	3.07	5.04	4.85	4.81	1.78	.63	.92	.70	.20	25.91
1906	.35	.91	1.70	3.08	3.02	2.47	2.08	3.42	2.37	2.40	.41	1.05	23.26

FORT ROBINSON, DAWES COUNTY.

Normal	0.68	0.66	1.22	1.72	2.64	2.82	2.09	1.61	1.03	1.33	0.40	0.70	16.79
1896	1.30	.50	1.50	.65	2.05	1.30	.80	.50	2.20	1.20	.60	.00	12.60
1897	1.90	T.	.50	.40	.65	1.49	3.60	T.	T.	T.	.65	1.30	10.49
1898	1.70	.20	1.30	.50	4.07	2.09	2.19	.05	.76	.33	.46	.51	14.16
1899	.27	.56	1.76	1.30	3.00	1.80	.97	1.55	.50	1.70	.25	.69	14.35
1900	.17	1.14	.27	4.10	.95	1.05	3.45	1.95	4.00	1.50	.15	.90	19.63
1901	.10	1.16	1.40	2.50	2.82	4.66	1.52	1.16	1.44	2.11	.05	.89	19.81
1902	.69	.65	1.91	1.40	2.56	3.74	1.88	1.52	1.61	.65	.25	2.65	19.51
1903	.60	.60	1.75	1.21	2.29	.71	4.70	2.53	1.17	.85	.10	.38	16.89
1904	.20	.47	.10	1.38	1.95	4.40	.93	2.21	1.50	.46	T.	.32	13.92
1905	1.13	.02	.38	.....	4.11	2.44	3.92	2.23	.39	1.15	.25	.20	.....
1906	.37	.99	1.80	2.30	3.94	2.83	1.10	3.23	3.48	2.79	.32	.37	23.52

WHITE RIVER AND HAT CREEK DRAINAGE BASINS.

DESCRIPTION OF BASINS.

The headwaters of White River and Hat Creek lie in Dawes and Sioux counties, in the northwestern part of Nebraska, at an elevation of about 4,800 feet above sea level, and both streams unite with the rivers to which they are tributary in South Dakota, Hat Creek joining the Cheyenne and White River the Missouri. Both drain areas of exceedingly rough, broken country, comprising what are popularly known as the Badlands. The characteristic formation of this region is a soft shale or slate-colored clay which has been carved by erosion into many fantastic shapes, giving rise to such local names as Big Badlands, Good Badlands, Toadstool Park, etc. The streams furnish considerable water for irrigation, but most of the ditches are small and operated by individual farmers. The principal crops are grain and hay for the herds of cattle that range the district.

Only one gaging station has been maintained in this basin in Nebraska—that on White River near Crawford during the season of 1897.

WHITE RIVER NEAR CRAWFORD.

A station was established June 26, 1897, and discontinued in the fall of the same year. It was located 6 miles southwest of Crawford, in the canal of the Crawford Water Power and Irrigation Company, into which the entire flow of White River was diverted. The gage was a vertical staff fastened to a stop gate in the canal.

Discharge measurements of White River near Crawford, 1897.

Date.	Hydrographer.	Gage height.	Discharge.	Date.	Hydrographer.	Gage height.	Discharge.
		Feet.	*Sec.-ft.*			*Feet.*	*Sec.-ft.*
June 16	O. V. P. Stout	0.42	14.4	September 20	A. B. McCoskey	0.62	10.4
July 21	do	.62	14.2	September 21	do	.64	11
August 14	do	.60	12.1	October 15	do	.89	15
September 6	do	.40	8.9	November 5	do	.92	16

Mean daily gage height, in feet, of White River near Crawford, 1897

Day.	July.	Aug.	Sept.	Oct.	Day.	July.	Aug.	Sept.	Oct.
1		0.40	0.40	0.71	17	0.30	0.60	0.70	0.90
2		.40	.40	.70	18	.55	.60	.62	.89
3		.60	.40	.70	19	.80	.60	.68	.87
4		.70	.40	.75	20	.70	.50	.60	.89
5		.70	.40	.73	21	.60	.50	.63	.90
6		.70	.43	.76	22	.55	.55	.68	.90
7		.60	.40	.77	23	.55	.50	.65	.88
8		.60	.43	.76	24	.50	.50	.68	.88
9		.70	.50	.68	25	.65	.50	.69	.82
10		.70	.63	.73	26	.55	.40	.70	.82
11		.70	.65	.75	27	55	.45	.69	.82
12		.60	.70	.82	28	.65	.40	.69	.91
13	0.40	.55	.65	.86	29	.50	.40	.69	.91
14	.30	.60	.63	.82	30	.50	.45	.70	.91
15	.40	.60	.63	.84	31	.45	.45		
16	.35	.60	.60	.84					

MISCELLANEOUS MEASUREMENTS IN WHITE RIVER AND HAT CREEK BASINS.

The following discharge measurements have been made in the drainage basins of White River and Hat Creek:

Miscellaneous discharge measurements in White River and Hat Creek basins, 1896–1902.

Stream.	Locality.	Date.	Hydrographer.	Discharge.
				Second-feet.
Ash Creek	Sec. 12, T. 32 N., R. 51 W.	Sept. 21, 1898	A. B. McCoskey	0.5
Do	Sec. 13, T. 32 N., R. 51 W.	May 15, 1899	C. B. Channel	.5
Do	Sec. 6, T. 32 N., R. 50 W. *a*	do	do	.8
Ash Creek, East Branch	Sec. 30, T. 32 N., R. 50 W. *b*	June 25, 1896	E. T. Youngfelt	1.1
Do	Sec. 30, T. 32 N., R. 50 W. *c*	May 15, 1899	C. B. Channel	3.3
Do	Sec. 33, T. 32 N., R. 50 W. *d*	Aug. 18, 1899	A. B. McCoskey	.3
Do	Sec. 30, T. 32 N., R. 50 W. *e*	June 22, 1900	T. J. O'Keefe	.2
Do	Sec. 31, T. 32 N., R. 50 W. *e*	July 17, 1900	A. B. McCoskey	.4
Do	Sec. 30, T. 32 N., R. 50 W. *e*	Aug. 20, 1900	T. J. O'Keefe	0
Ash Creek, West Branch.	N. line sec. 25, T. 32 N., R. 51 W.	June 25, 1896	E. T. Youngfelt	1.7
Do	Sec. 2, T. 32 N., R. 51 W. *f*	Aug. 18, 1897	A. B. McCoskey	1.0
Do	Sec. 25, T. 32 N., R. 51 W.	May 15, 1899	C. B. Channel	.2
Do	Sec. 24, T. 32 N., R. 51 W. *e*	June 22, 1900	T. J. O'Keefe	.1
Do	do	Aug. 20, 1900	do	0
Do	Sec. 35, T. 32 N., R. 51 W. *g*	July 17, 1900	A. B. McCoskey	1.0
Beaver Creek	Sec. 20, T. 44 N., R. 46 W.	May 22, 1899	C. B. Channel	9
Boggy Creek	Line bet. secs. 17, 18, T. 32 N., R. 54 W.	May 8, 1897	A. B. McCoskey	.1
Do	N. line sec. 31, T. 33 N., R. 54 W.	do	do	.3
Do	do	May 24, 1899	do	.1
Bordeaux Creek, Big	Sec. 25, T. 33 N., R. 48 W.	Sept. 22, 1898	do	1.9
Chadron Creek	Sec. 18, T. 32 N., R. 48 W. *h*	Sept. 14, 1897	do	1.6
Do	do. *h*	May 17, 1899	C. B. Channel	2.2
Do	Sec. 18, T. 32 N., R. 48 W. *i*	Sept. 14, 1897	A. B. McCoskey	1.2
Do	do. *i*	May 17, 1899	C. B. Channel	2.2
Do	Sec. 36, T. 33 N., R. 49 W.	Sept. 23, 1898	A. B. McCoskey	1.2
Do	do	May 17, 1899	C. B. Channel	8.7
Cottonwood Creek, Big	Sec. 20, T. 33 N., R. 51 W. *j*	June 25, 1896	E. T. Youngfelt	.2
Cottonwood Creek, Little.	Sec. 7, T. 32 N., R. 51 W.	June 25, 1896	do	.1
Do	W. line sec. 7, T. 32 N., R. 51 W.	May 15, 1899	C. B. Channel	.3
Do	Below mouth Spring Creek	May 16, 1899	do	.4
Dead Horse Creek	Sec. 31, T. 33 N., R. 50 W.	Sept. 21, 1898	A. B. McCoskey	*k* .3
Do	Sec. 7, T. 32 N., R. 49 W.	Sept. 23, 1898	do	*k* .6
Do	N. line sec. 31, T. 33 N., R. 49 W.	May 17, 1899	C. B. Channel	3.5
Do	Sec. 32, T. 33 N., R. 49 W. *l*	do	do	4
Deadman Creek	Sec. 19, T. 30 N., R. 52 W. *m*	Oct. 2, 1900	T. J. O'Keefe	1.8
Do	Sec. 1, T. 30 N., R. 53 W. *n*	do	do	1.1
Fort Robinson ditch	Fort Robinson	June 24, 1896	E. T. Youngfelt	.8
Do	do	Apr. 27, 1898	Glenn E. Smith	2
Hat Creek, East	Sec. 23, T. 32 N., R. 55 W.	July 10, 1897	A. B. McCoskey	.3
Do	Sec. 10, T. 32 N., R. 55 W. *o*	do	do	1
Hat Creek, West	Sec. 10, T. 32 N., R. 55 W. *p*	do	do	.5
Do	Sec. 10, T. 32 N., R. 55 W. *q*	do	do	1.6
Do	Sec. 16, T. 32 N., R. 55 W. *r*	July 16, 1897	do	.7
Do	Sec. 23, T. 33 N., R. 55 W.	Sept. 30, 1898	do	1.4
Do	Sec. 26, T. 33 N., R. 55 W. *s*	May 24, 1899	do	3.6
Indian Creek	N. line sec. 33, T. 32 N., R. 50 W.	Aug. 18, 1899	do	.5
Jim Creek	Sec. 14, T. 33 N., R. 57 W. *t*	July 22, 1897	do	.2
Monroe Creek	Sec. 27, T. 33 N., R. 56 W. *u*	July 20, 1897	do	.2
Do	Sec. 33, T. 33 N., R. 56 W. *v*	July 21, 1897	do	1
Do	Sec. 14, T. 33 N., R. 56 W.	Sept. 30, 1898	do	*k* .3
Do	Sec. 33, T. 33 N., R. 56 W. *v*	Sept. 24, 1900	T. J. O'Keefe	.8

a At mouth.
b One-half mile above mouth.
c Head Tomlin ditch.
d Head Sheldon ditch.
e One-fourth mile above fork.
f Head Mace ditch.
g Above Broadhurst dam.
h Above Chadron W. W.
i Below Chadron W. W.
j Six miles west of Whitney.
k Estimated.
l At Slattery dam.
m Head of Phillips ditch.
n Head of P. R. ditch.
o Near mouth.
p Above mouth of East Hat.
q Below confluence.
r Head of Steel ditch.
s Above Coffee ditch.
t Above Woodruff dam.
u Head of Schilt ditch.
v Head of Wilcox ditch.

Miscellaneous discharge measurements in White River and Hat Creek basins, 1896–1902—Continued.

Stream.	Locality.	Date.	Hydrographer.	Discharge.
				Second-feet.
Soldier Creek	Fort Robinson	June 24, 1896	E. T. Youngfelt	3.2
Do	Sec. 5, T. 31 N., R. 53 W.	Aug. 14, 1897	O. V. P. Stout	2.3
Do	Fort Robinson	Apr. 27, 1898	Glenn E. Smith	3.6
Do	do	Aug. 22, 1900	T. J. O'Keefe	1.8
Do	do	Sept. 22, 1900	do	2.5
Do	do	Oct. 31, 1898	Glenn E. Smith	4
Sowbelly Creek	Sec. 7, T. 32 N., R. 55 W. [a]	July 16, 1897	A. B. McCoskey	1.4
Do	Bodarc	July 14, 1897	do	1.5
Do	Bridge S. of Gilchrist	July 24, 1897	do	.1
Do	Sec. 19, T. 33 N., R. 55 W.	Sept 30, 1898	do	[b] 1
Do	N. line sec. 19, T. 32 N., R. 55 W.	Aug. 1, 1899	do	1.4
Do	Sec. 24, T. 32 N., R. 56 W. [c]	Sept. 24, 1900	T. J. O'Keefe	3.2
Spring Creek	Sec. 7, T. 32 N., R. 51 W. [d]	May 16, 1899	C. B. Channel	.3
Squaw Creek	Sec. 1, T. 31 N., R. 52 W.	June 24, 1896	E. T. Youngfelt	.6
Do	Sec. 15, T. 33 N., R. 57 W.	July 22, 1897	A. B. McCoskey	.1
Do	Sec. 28, T. 31 N., R. 51 W.	May 11, 1899	C. B. Channel	1.2
Do	Sec. 18, T. 31 N., R. 51 W.	do	do	.3
Do	Sec. 19, T. 31 N., R. 51 W. [e]	do	do	.8
Do	Sec. 36, T. 32 N., R. 52 W. [f]	May 12, 1899	do	.7
Trunk Butte Creek	N. line sec. 36, T. 33 N., R. 50 W.	May 17, 1899	do	1.4
Do	do	Aug. 18, 1899	A. B. McCoskey	.3
Warbonnet Creek	Sec. 21, T. 33 N., R. 56 W.	July 23, 1897	do	.5
Do	do	Sept. 29, 1898	do	1.2
Do	do	May 25, 1899	do	2.5
Do	do	Sept. 25, 1900	T. J. O'Keefe	.8
Warbonnet, Middle Branch.	Sec. 31, T. 33 N., R. 56 W. [g]	July 21, 1898	A. B. McCoskey	.3
Warbonnet, Spring Branch.	Sec. 32, T. 33 N., R. 56 W. [h]	do	do	.3
White Clay Creek	N. line sec. 2, T. 31 N., R. 52 W.	June 24, 1896	E. T. Youngfelt	4
Do	Sec. 1, T. 31 N., R. 52 W.	June 24, 1886		4
Do	Sec. 2, T. 31 N., R. 52 W.	Sept. 21, 1898		.8
Do	Sec. 32, T. 15 N., R. 51 W.	May 11, 1899	C. B. Channel	.7
Do	Sec. 1, T. 31 N., R. 52 W.	Aug. 23, 1900	T. J. O'Keefe	1.5
White River	Sec. 23, T. 31 N., R. 53 W.	June 24, 1896	E. T. Youngfelt	23.3
Do	Sec. 23, T. 31 N., R. 53 W. [i]	Aug. 14, 1897	O. V. P. Stout	11.9 / 8.0 / [j] 19.9
Do	Bridge below Crawford	do	do	
Do	Crawford	June 24, 1896	E. T. Youngfelt	30.7
Do	Whitney	June 25, 1896	do	27.2
Do	do	Sept. 21, 1898	A. B. McCoskey	[b] 8
Do	do	May 15, 1899	C. B. Channel	10.4
Do	do	Sept. 3, 1900	T. J. O'Keefe	5
Do	Crawford	Oct. 31, 1898	Glenn E. Smith	13
Do	do	July 11, 1901	B. E. Forbes	11.5
Do	do	Aug. 24, 1903	J. C. Stevens	14
Do	do	May 27, 1903	do	18.9
Do	do	Apr. 27, 1903	do	31
Do	1 mile below mouth of Kyle Creek.	Aug. 11, 1897	A. B. McCoskey	6.6
Do	Bridge below Crawford	Sept. 9, 1897	do	7
Do	do	Sept. 20, 1898	do	7.7
Do	do	May 17, 1899	do	18.7
Do	do	May 22, 1899	do	45.89
Do	do	Aug. 19, 1899	do	16.2
Do	do	July 16, 1900	do	28.3
Do	do	Sept. 1, 1900	T. J. O'Keefe	13.5
Do	6 miles W. of Crawford	Oct. 31, 1898	Glenn E. Smith	21
Do	At Andrew's siding	May 26, 1899	C. B. Channel	4.9
Do	Sec. 33, T. 31 N., R. 53 W. [k]	Aug. 13, 1897	A. B. McCoskey	5.7
Do	Sec. 23, T. 31 N., R. 53 W. [i]	Sept. 24, 1898	do	13.1
Do	do [i]	July 16, 1900	do	15.48
Do	do [i]	Aug. 22, 1900	T. J. O'Keefe	14
Do	do	July 24, 1903	C. Spearman	16.3
Do	Sec. 31, T. 31 N., R. 54 W.	May 19, 1899	A. B. McCoskey	4.4
Do	Sec. 34, T. 32 N., R. 52 W.	June 2, 1902	Adna Dobson	65
Do	Sec. 25, T. 32 N., R. 52 W.	Aug. 20, 1902	B. E. Forbes	10.4

[a] Above head of Shaefer ditch.
[b] Estimated.
[c] Head of Nutto's ditch.
[d] At mouth.
[e] Head of Daniel & Stetson ditch.
[f] Head of Cooper ditch.
[g] Head of Garton ditch.
[h] Head of Biehle ditch.
[i] Head of Crawford ditch.
[j] Discharge at Crawford. (See note at end of this table.)
[k] Railroad bridge above Glen.

72607—IRR 230—09——16

Miscellaneous discharge measurements in White River and Hat Creek basins 1896–1906—Continued.

Stream.	Locality.	Date.	Hydrographer.	Discharge.
				Second-feet.
White River	Sec. 23, T. 31 N., R. 53 W.[a]	Sept. 20, 1897	A. B. McCoskey	10.44
Do	Bridge below Crawford	do	do	7.53 } [b]17.97
Do	Sec. 23, T. 31 N., R. 53 W.[a]	Oct. 18, 1897	do	15.25
Do	Bridge below Crawford	do	do	10.13 } [b]25.38
Do	Sec. 23, T. 31 N., R. 53 W.[a]	Nov. 5, 1897	do	15.87
Do	Bridge below Crawford	do	do	10.58 } [b]26.45
Do	Sec. 23, T. 31 N., R. 53 W.[a]	Apr. 27, 1898	Glenn E. Smith	18.3
Do	Bridge below Crawford	do	do	11.1 } [b]29.4
Do	Sec. 23, T. 31 N., R. 53 W.[a]	May 19, 1899	A. B. McCoskey	16.7
Do	Bridge below Crawford	do	do	18.05 } [b]34.75

[a] Head of Crawford ditch.

[b] Discharge at Crawford. When these measurements were taken the water was all diverted into the Crawford ditch. The gagings at the bridge below Crawford show only water accumulated between the two points, from Soldier Creek, seepage, springs, etc. The actual discharge of the stream at Crawford, with the Crawford ditch closed, would be a little less than the sum of the discharges at the two points on the same date.

INDEX.

A.

Page.

Acknowledgments to those aiding 5
Acre-foot, definition of 7
Agee, rainfall at 236, 237
Ainsworth,
  Bone Creek at:
    discharge measurement 213
Albion,
  Beaver Creek at:
    discharge measurements 157
Alcova, rainfall at 163, 172
Alliance, rainfall at 163, 171
Ansley, rainfall at 162, 168
Antelope Creek, discharge measurement of ... 233
Arickaree Fork at—
  Haigler:
    discharge measurements 213
Arlington,
  Elkhorn River at:
    description of 150
    discharge, daily 153–155
    discharge, monthly 156
    discharge measurements 150, 157
    gage heights 151–153
Arnold,
  South Loup River at:
    discharge measurement 161
Ash Creek (Niobrara River drainage), discharge measurement of 233
Ash Creek (White River drainage), discharge measurements of 240
Ashland, rainfall at 162, 163
  Platte River at:
    discharge measurements 161
  Salt Creek at:
    discharge measurement 161
Atkinson,
  Elkhorn River at:
    discharge measurements 157
Aurora, rainfall at 163, 169
Ayr,
  Little Blue River at:
    discharge measurement 211

B.

Baker Creek, discharge measurement of 233
Bassett,
  Elk Creek at:
    discharge measurement 234
Bear Creek, discharge measurement of 233
Beatrice,
  Big Blue River at:
    discharge measurements 211
Beaver City, rainfall at 214, 216
Beaver Creek (of Kansas River drainage) at—
  Geneva:
    discharge measurements 211

Page.

Beaver Creek (of Niobrara River drainage), discharge measurement of 233
  at Ravenna:
    discharge measurement 233
Beaver Creek (of Platte River drainage) at—
  Albion:
    discharge measurement 157
  Genoa:
    discharge measurements 157
Beaver Creek (of White River drainage), discharge measurement of 240
Belle,
  Niobrara River at:
    discharge measurement 234
Benkelman, rainfall at 214, 218
  Republican River at:
    description of 176–177
    discharge, daily 180–182
    discharge, monthly 182
    discharge measurements 177
    gage heights 177–180
  Republican River (South Fork) near:
    description of 199–200
    discharge, daily 203–204
    discharge, monthly 205
    discharge measurements 200, 213
    gage heights 200–203
Big Blue River at—
  Beatrice:
    discharge measurements 211
  Blue Springs:
    discharge measurement 211
  Crete:
    discharge measurements 211
  De Witt:
    discharge measurements 211
  Milford:
    discharge measurement 211
  Oak:
    discharge measurement 211
  Seward:
    discharge measurements 211
  Wilbur:
    discharge measurement 211
  Wymore:
    discharge measurements 211
Big Bordeaux Creek, discharge measurement of 240
Big Cottonwood Creek (Niobrara River drainage), discharge measurement of ... 233
Big Cottonwood Creek (White River drainage), discharge measurement of ... 240
Big Spring,
  South Platte River at:
    description of 108
    discharge, daily 109
    discharge measurements 108
    gage heights 108–109

Page.
Birdwood Creek, discharge measurements of.. 157
at Sutherland:
discharge measurements..... 157
Blue Creek, discharge measurements of..... 157
at Lown Bridge:
discharge measurements..... 157
Blue Springs,
Big Blue River at:
discharge measurement..... 211
Boardman Creek, discharge measurement of. 233
Bodarc,
Sowbelly Creek at:
discharge measurement..... 241
Boggy Creek, discharge measurements of..... 240
Bone Creek, discharge measurement of..... 233
at Ainsworth:
discharge measurement..... 233
at Long Pine:
discharge measurements..... 233
Bostwick,
Republican River at:
description of..... 183
discharge, daily..... 197–198
discharge, monthly..... 198–199
discharge measurements..... 185
gage heights..... 189–191
Boulder, rainfall at..... 163, 175
Brewster,
North Loup River at:
discharge measurements..... 160
Bridgeport,
North Platte River at:
description of..... 77–78
discharge, daily..... 81–83
discharge, monthly..... 84
discharge measurements..... 78
gage heights..... 78–81
Broken Bow, rainfall at..... 163, 168
Brownlee,
North Loup River at:
discharge measurements..... 160
Buck Creek, discharge measurement of..... 233
Buffalo Creek (of Kansas River drainage),
discharge measurements of..... 211
Buffalo Creek (of Platte River drainage),
discharge measurements of..... 157
Burton Creek, discharge measurement of..... 233
Burwell,
Calamus River at:
discharge measurements..... 157
North Loup River at:
discharge measurements..... 160
rainfall at..... 162, 167
Bush Creek, discharge measurement of..... 233
Butte, discharge measurement at..... 234
Keyapaha River at:
discharge measurement..... 234
Niobrara River at:
discharge measurement..... 235

C.

Calamus River, discharge measurements of.. 157
at Burwell:
discharge measurements..... 157
Callaway, rainfall at..... 162, 168
South Loup River at:
discharge measurements..... 161
Cambridge, Page.
Medicine Creek at:
discharge measurement..... 212
Republican River at:
discharge measurement..... 213
Camp Clarke,
North Platte River at:
description of..... 71
discharge, daily..... 74–76
discharge, monthly..... 77
discharge measurements..... 71, 160
gage heights..... 71–74
rainfall at..... 163, 171
Cascade,
North Loup River at:
discharge measurement..... 160
Castle Rock, rainfall at..... 163, 175
Cedar Creek (of Niobrara River drainage),
discharge measurement of..... 233
Cedar Creek (of Platte River drainage),
discharge measurements of..... 157
Cedar Rapids,
Cedar River at:
discharge measurements..... 157
Cedar River at—
Cedar Rapids:
discharge measurements..... 157
Ericson:
discharge measurements..... 157
Fullerton:
discharge measurements..... 157
Center Creek, discharge measurements of..... 211
Central City,
Plate River at:
discharge measurement..... 161
rainfall at..... 163, 169
Chadron Creek, discharge measurements of.. 240
Champion,
Frenchman River at:
discharge measurement..... 212
Cherry County, lakes in:
description..... 231–232
gage heights..... 232–233
Cheyenne, rainfall at..... 163, 174
Clear Creek, discharge measurements of..... 157
Coldwater Creek, discharge measurement of.. 157
Columbus,
Loup River at:
description of..... 111
discharge, daily..... 113–118
discharge, monthly..... 124–126
discharge measurements..... 13, 20, 112
gage heights..... 118, 124
Platte River near:
description of..... 42–43
discharge, daily..... 49–53
discharge, monthly..... 54–55
discharge measurements..... 43–44, 160
gage heights..... 44–48
rainfall at..... 162, 165
Cook Creek, discharge measurements of..... 212
Coon Creek, discharge measurements of..... 157
Correction curves, construction and use of... 14–15
Crawford,
White River near:
description of..... 239
discharge measurements..... 239, 241–242
gage heights..... 239

Crete, Page.
Big Blue River at:
discharge measurements..... 211
Crooked Creek (of Kansas River drainage),
discharge measurements of..... 212
Crooked Creek (of Niobrara River drainage),
discharge measurements of..... 233
Culbertson, rainfall at..... 214,217
Republican River at:
discharge measurement..... 212–213
Frenchman River at:
discharge measurements..... 212
Current meters, use of..... 9
Curtis,
Medicine Creek at:
discharge measurement..... 212
rainfall at..... 214,217

D.

Dannebrog,
Oak Creek at:
discharge measurement..... 160
David City, rainfall at..... 162,165
Dead Horse Creek, discharge measurements of 240
Deadman Creek, discharge measurements of. 240
Deer Creek, discharge measurements of..... 233
Definitions, list of..... 7
De Witt,
Big Blue River at:
discharge measurements..... 211
Denver, rainfall at..... 163,175
Dickens formula, discussion of..... 23–24
Discharge, computation of..... 15–17
Dismal River at—
Dunning:
discharge measurements..... 157
Douglas,
North Platte River at:
discharge measurements..... 160
Dry Brook at—
Ericson:
discharge measurements..... 157
Dunlap,
Niobrara River at:
discharge measurement..... 235
Dunning,
Dismal River at:
discharge measurements..... 157

E.

Eagle Creek, discharge measurements of..... 233
Edison,
Republican River at:
discharge measurement..... 213
Elk Creek at—
Bassett:
discharge measurement..... 234
Elkhorn River at or near—
Arlington:
description of..... 150
discharge, daily..... 153–155
discharge, monthly..... 156
discharge measurements..... 150,157
gage heights..... 151–153
Atkinson:
discharge measurements..... 157
Ewing:
discharge measurements..... 158
Elkhorn River at or near—Continued. Page.
Norfolk:
description of..... 140
discharge, daily..... 145–148
discharge, monthly..... 149
discharge measurements..... 141
gage heights..... 141–145
O'Neill:
discharge measurements..... 158
Waterloo:
discharge measurements..... 158
Elkhorn River basin, description of..... 31,140
hydrographic data in..... 140–156
rainfall in..... 30,32
run-off of..... 32
Elkhorn River (North Fork) at—
Norfolk:
discharge measurements..... 158
Norfolk Junction Bridge:
discharge measurements..... 158
Enders,
Frenchman River at:
discharge measurement..... 212
Equivalents, list of..... 7–9
Ericson,
Cedar River at:
discharge measurements..... 157
Dry Brook at:
discharge measurements..... 157
rainfall at..... 162,166
Evaporation, observations on..... 34
Ewing,
Elkhorn River at:
discharge measurements..... 158

F.

Fairbanks,
North Platte River at:
discharge measurement..... 160
Fairfield Creek, discharge measurement of... 234
Fanning, J. T., run-off formula of..... 23
Flag Creek, discharge measurements of..... 212
Fort Laramie, rainfall at..... 163,172
Fort Morgan, rainfall at..... 163,174
Fort Niobrara,
Minnechaduza Creek at:
discharge measurements..... 234
Niobrara River at:
discharge measurement..... 235
Fort Robinson, discharge measurements of .. 240
rainfall at..... 236,238
Soldier Creek at:
discharge measurements..... 241
Franklin, rainfall at..... 214,215
Republican River at:
discharge measurement..... 213
Fremont,
Platte River at:
discharge measurements..... 160–161
rainfall at..... 162,164
Fremont Creek, discharge measurements of.. 158
Frenchman River, discharge measurements
of..... 212
at Champion:
discharge measurement..... 212
at Culberson:
discharge measurements..... 212
at Enders:
discharge measurement..... 212

Frenchman River—Continued. Page.
at Maranville:
discharge measurement..... 212
at Palisade:
description of..... 207
discharge, daily..... 209–210
discharge, monthly..... 211
discharge measurements..... 208, 212
gage heights..... 208–209
at Wauneta:
description of..... 205–206
discharge, daily..... 207
discharge measurements..... 206, 212
gage heights..... 206–207
Fullerton,
Cedar River at:
discharge measurements..... 157
Loup River at:
discharge measurements..... 159

G.

Gage heights, correction of..... 12–15
Gaging stations, map showing..... 6
Geneva,
Beaver Creek at:
discharge measurements..... 211
Genoa,
Beaver Creek at:
discharge measurements..... 157
rainfall at..... 162, 165
Georgetown,
South Loup River at:
discharge measurement..... 161
Gering,
North Platte River at:
description of..... 66
discharge, daily..... 68–70
discharge, monthly..... 70
discharge measurements..... 66, 160
gage heights..... 66–68
rainfall at..... 163, 171
Glenwood,
Wood River at:
discharge measurement..... 162
Glenwood Creek, discharge measurements of. 158
Golden Creek, discharge measurements of... 158
Goose Creek, discharge measurements of..... 158
Gordon Creek, discharge measurement of.... 234
Gothenburg, rainfall at..... 163, 170
Grand Island,
Platte River at:
discharge measurements..... 161
rainfall at..... 163, 169
Greeley, rainfall at..... 163, 174
Ground storage, relation of, to run-off..... 25–26

H.

Haigler,
Arickaree Fork at:
discharge measurement..... 213
Porter's ditch at:
discharge measurement..... 212
rainfall at..... 214, 219
Republican River at:
discharge measurements..... 213
Harlacher formula, use of..... 16–17
Hastings, rainfall at..... 163, 170
Hat Creek, basin of, description of..... 239
hydrographic data in..... 240

Page.
Hayes Center, rainfall at..... 214, 217
Hay Springs, rainfall at..... 236, 238
Holdrege, rainfall at..... 214, 215
Holt Creek, discharge measurement of..... 234
Horse Creek (of Kansas River drainage), discharge measurements of..... 212
Horse Creek (of Platte River drainage), discharge measurements of..... 158
Horsehead Creek, discharge measurement of. 234
Hydrographic data, nature of..... 33–34

I.

Ice, discharge under..... 25
Imperial, rainfall at..... 214, 218
Indian Creek (Kansas River drainage), discharge measurements of..... 212
Indian Creek (White River drainage), discharge measurement of..... 240
Ives,
Republican River at:
discharge measurement..... 213
Rock Creek at:
discharge measurement..... 213

J.

Julesburg,
South Platte River at:
description of..... 101
discharge, daily..... 104–106
discharge, monthly..... 107
discharge measurements..... 101, 162
gage heights..... 101–104

K.

Kansas River basin, description of..... 175–176
gaging stations in..... 176
hydrographic data of..... 176–220
Kearney, evaporation and seepage at..... 34
Platte River at:
discharge measurements..... 161
rainfall at..... 163, 170
Kennedy, rainfall at..... 236, 238
Keyapaha River, discharge measurements of. 234
at Butte:
discharge measurements..... 234
Kimball, rainfall at..... 163, 173
Kirkwood, rainfall at..... 236, 237

L.

Lake Creek, discharge measurements of..... 158
Lander, rainfall at..... 163, 172
Lavaca,
Niobrara River at:
discharge measurement..... 235
Laramie, rainfall at..... 163, 173
Lawrence Fork, discharge measurements of.. 158
Leroy, Colo., rainfall at..... 214, 220
Lewellen,
North Platte River at:
discharge measurements..... 160
Lexington,
Platte River near:
description of..... 35–36
discharge, daily..... 39–41
discharge, monthly..... 42
discharge measurements..... 36, 161
gage heights..... 37–39
rainfall at..... 163, 170

Page.
Lincoln, flood at, view of 26
rainfall at 162, 163
Salt Creek at:
discharge measurement 161
Litchfield,
Mud Creek at:
discharge measurement 160
Little Blue River, discharge measurement of 211
at Ayr:
discharge measurement 211
Little Cottonwood Creek, discharge measurements of 240
Lodgepole, rainfall at 163, 173
Lodgepole Creek, discharge measurements of 158
at Chappell:
discharge measurement 159
at Kimball:
discharge measurements 158
at Lodgepole:
discharge measurement 159
at Sidney:
discharge measurement 159
Lonergan Creek, discharge measurements of 159
Long Pine,
Bone Creek at:
discharge measurements 233
Long Pine Creek at:
discharge measurements 234
Lookingglass Creek, discharge measurements of 159
Lost Creek, discharge measurement 212
Loup, rainfall at 162, 167
Loup River, channel of, changes in 12–15
correction curves for 14
cross sections of, figure showing 11
discharge measurement of 159
rating curve of, figure showing 12
rating table for 13
Loup River at or near—
Columbus:
description of 111
discharge, daily 113–118
discharge, monthly 124–126
discharge measurements 13, 20, 112
gage heights 118–124
Fullerton:
discharge measurements 159
Loup River basin, description of 31, 110
hydrographic data in 111–139
rainfall on 29, 32
run-off of 32
Lown Bridge,
Blue Creek at:
discharge measurements 157
Lusk, rainfall at 163, 172
Lynch, rainfall at 236, 237

M.

McCook,
Republican River at:
discharge measurements 213
Madrid, rainfall at 214, 218
Map of Nebraska, showing surface waters 6
Maranville,
Frenchman River at:
discharge measurement 212
Marquette, rainfall at 163, 169
Marsland,
Niobrara River at:
discharge measurements 234
Mathews Creek, discharge measurement of 159
Medicine Creek at—
Cambridge:
discharge measurement 212
Curtis:
discharge measurement 212
Methodist Creek, discharge measurement of 212
Middle Creek, discharge measurement of 234
Middle Loup River, discharge measurements of 159–160
at Arcadia:
discharge measurements 160
at Boelus:
discharge measurement 160
at Dunning:
discharge measurements 160
at Gates:
discharge measurement 159
at Loup City:
discharge measurement 160
at Mullen:
discharge measurement 160
description of 133
discharge, daily 136–139
discharge, monthly 139
discharge measurements 134, 160
gage heights 134–136
at Seneca:
discharge measurements 160
at Thedford:
discharge measurements 160
Milford,
Big Blue River at:
discharge measurement 211
Mills,
Spring Creek at:
discharge measurement 236
Minden, rainfall at 214, 215
Miner's inch, definition of 7
Minnechaduza Creek, discharge measurements 234
at Fort Niobrara:
discharge measurements 234
at Valentine:
discharge measurements 234
reservoir and power plant on, view of 220
Mitchell,
North Platte River at:
description of 58–59
discharge, daily 62–64
discharge, monthly 65
discharge measurements 59
gage heights 59–62
Monroe Creek, discharge measurements of 240
Moraine, rainfall at 163, 174
Moulton,
North Loup River at:
discharge measurement 160
Mud Creek at—
Litchfield:
discharge measurement 160
Muddy Creek, discharge measurement of 212
Naponee,
Naponee Creek at:
discharge measurement 212

Naponee—Continued. Page.
Republican River at:
discharge measurement 213
Turkey Creek at:
discharge measurement 213
Newell, F. H., on rainfall and run-off 26–27
Newman Creek, discharge measurement of 234
Niobrara,
Niobrara River at:
description of 231
discharge measurements 231, 234–235
gage heights 231
Niobrara River, bluffs of, view of 220
canyons of, view of 220
Niobrara River at or near—
Belle:
discharge measurement 235
Butte:
discharge measurement 235
Dunlap:
discharge measurement 235
Fort Niobrara:
discharge measurement 235
Lavaca:
discharge measurement 235
Marsland:
discharge measurements 234
Niobrara:
description of 231
discharge measurements 231, 234–235
gage heights 231
Valentine:
description of 222–223
discharge, daily 227–229
discharge, monthly 230
discharge measurements 20–21, 223, 234
gage heights 224–227
Niobrara River basin, description of 31, 220–222
gaging stations in 222
hydrographic data in 222–238
rainfall on 30, 32
run-off of 32
Norfolk,
Elkhorn River near:
description of 140
discharge, daily 145–148
discharge, monthly 149
discharge measurements 141
gage heights 141–145
Elkhorn River (North Fork) at:
discharge measurements 158
rainfall at 162, 164
Norfolk Junction Bridge,
Elkhorn River (North Fork) at:
discharge measurements 158
North Loup, rainfall at 162, 166
North Loup River at or near—
Brewster:
discharge measurements 160
Brownlee:
discharge measurements 160
Burwell:
discharge measurements 160
Cascade:
discharge measurement 160

North Loup River at or near—Cont'd. Page.
Moulton:
discharge measurement 160
St. Paul:
description of 126–127
discharge, daily 130–132
discharge, monthly 132–133
discharge measurements 127, 160
gage heights 127–129
North Platte,
North Platte River at:
description of 84–85
discharge, daily 92–97
discharge, monthly 98–99
discharge measurements 85–86
gage heights 86–92
rainfall at 163, 171
South Platte River at:
discharge measurements 161–162
North Platte River, discharge measurements of 160
at Bridgeport:
description of 77–78
discharge, daily 81–83
discharge, monthly 84
discharge measurements 78
gage heights 78–81
at Camp Clarke:
description of 71
discharge, daily 74–76
discharge, monthly 77
discharge measurements 71, 160
gage heights 71–74
at Douglas:
discharge measurements 160
at Fairbanks, Wyo.:
discharge measurement 160
at Gering:
description of 66
discharge, daily 68–70
discharge, monthly 70
discharge measurements 66, 160
gage heights 66–68
at Lewellen:
discharge measurements 160
at Mitchell:
description of 58–59
discharge, daily 62–64
discharge, monthly 65
discharge measurements 59
gage heights 59–62
at North Platte:
description of 84–85
discharge, daily 92–97
discharge, monthly 98–99
discharge measurements 85–86
gage heights 86–92
at Sutherland:
discharge measurement 160
North Platte River basin, description of 31, 56–58
gaging stations in 58
hydrographic data in 58–99
rainfall in 29, 32
run-off of 32
Norton, rainfall at 214, 216

O.

Page.

Oak,
Big Blue River at:
discharge measurement 211
Oak Creek, discharge measurements of 160
Dannebrog:
discharge measurement 160
Oakdale, rainfall at 164
Oberlin, rainfall at 214, 216
Ogalalla,
South Platte River at:
discharge measurement 162
Omaha, rainfall at 162, 164
O'Neill,
Elkhorn River at:
discharge measurements 158
rainfall at 162, 165
Ord, rainfall at 162, 167
Orleans,
Republican River at:
discharge measurement 213
Oxford,
Republican River at:
discharge measurements 213

P.

Palisade,
Frenchman River at:
description of 207
discharge, daily 209–210
discharge, monthly 211
discharge measurements 208, 212
gage heights 208–209
Stinking Water at:
discharge measurement 213
Palmer, rainfall at 162, 166
Pawnee Creek, discharge measurements of 160
Paxton Spring, discharge measurement of 160
Pine Creek, discharge measurements of 235
Plain Creek, discharge measurement of 160
Platte Center,
Shell Creek at:
discharge measurements of 161
Platte River (proper), bed of, view of 36
discharge measurements in 161
Platte River (proper) at or near—
Ashland:
discharge measurement 161
Central City:
discharge measurement 161
Columbus:
description of 42–43
discharge, daily 49–53
discharge, monthly 54–55
discharge measurements 43–44, 160
gage heights 44–48
Fremont:
discharge measurements 160–161
Grand Island:
discharge measurements 161
Kearney:
discharge measurements 161
Lexington:
description of 35–36
discharge, daily 39–41
discharge, monthly 42
discharge measurements 36, 161
gage heights 37–39
Platte River (proper) at or near—Cont'd.
South Bend:
Page.
description of 55–56
discharge measurements 56, 161
gage heights 56
Valley:
discharge measurement 161
Platte River basin, hydrographic data in 35–175
rainfall in 162–175
See also particular tributaries.
Platte River (proper) basin, description of 34–35
floods in 25–27
gaging stations in 35
hydrographic data in 35–56
Plum Creek, discharge measurements of 235
Pole Creek, discharge measurement of 235
Prairie Creek, discharge measurement of 161
Precipitation. *See* Rainfall.
Pumpkinseed Creek, discharge measurements of 161

R.

Rafter, G. W., on rainfall and run-off 23
Rainfall, data on 27–32
records of, limitations of 22–23
relation of, to run-off 22–33
Rating curves, explanation of 9
Rating tables, construction and use of 9, 10
Ravenna,
Beaver Creek at:
discharge measurement 233
rainfall at 167, 168
South Loup River at:
discharge measurements 161
Rawlins, rainfall at 163, 173
Red Cloud, rainfall at 214
Red Deer Lake near—
Woodlake:
gage heights 232–233
Republican, rainfall at 214, 215
Republican River at—
Benkelman:
description 176–177
discharge, daily 180–182
discharge, monthly 182
discharge measurements 177, 213
gage heights 177–180
Bostwick:
description of 183
discharge, daily 197–198
discharge, monthly 198–199
discharge measurements 185
gage heights 189–191
Cambridge:
discharge measurement 213
Culbertson:
discharge measurement 212–213
Edison:
discharge measurement 213
Franklin:
discharge measurement 213
Haigler:
discharge measurement 213
Ives:
discharge measurement 213
McCook:
discharge measurement 213

Republican River at—Continued. Page.
Orleans:
discharge measurement 213
Oxford:
discharge measurements 213
Stratton:
discharge measurement 213
Superior:
description of 183–184
discharge, daily 193–196
discharge, monthly 198–199
discharge measurements 184–185
gage heights 186–189, 191–193
Warwick:
discharge measurement 213
Wray:
discharge measurement 213
Republican River basin, description of 31
rainfall on 29, 32
run-off of 32
Republican River (South Fork) near—
Benkelman:
description of 199–200
discharge, daily 203–204
discharge, monthly 205
discharge measurements 200, 213
gage heights 200–203
Rock Creek (Kansas River drainage) at—
Ives:
discharge measurements 213
Rock Creek (Niobrara River drainage), discharge measurement of 235
Rock Spring Creek, discharge measurement of 235
Run-off, data on 30–32
definition of 7
determination of 22–23, 24–25
data for 27–32
formulas for 23–24
relation of, to ground storage 25–26
to rainfall 22–23
Rush Creek, discharge measurement of 235
Ryves formula, discussion of 22–23

S.

St. Michaels,
South Loup River at:
discharge measurement 161
St. Paul.
Middle Loup River at:
description of 133
discharge, daily 136–139
discharge, monthly 139
discharge measurements 134
gage heights 134–136
North Loup River near:
description of 126–127
discharge, daily 130–132
discharge, monthly 133
discharge measurements 127, 160
gage heights 127–129
rainfall at 166
Salt Creek at—
Ashland:
discharge measurements 161
Lincoln:
discharge measurements 161
Sand Creek, discharge measurement of 161
Sandy Creek, discharge measurement of 235
Santee, rainfall at 236
Sappa Creek at—
Stamford:
discharge measurement 213
Schuyler,
Shell Creek at:
discharge measurement 161
Second-foot, definition of 7
Seepage, observations on 34
Seneca, rainfall at 162, 167
Seward,
Big Blue River at:
discharge measurements 211
Shell Creek at—
Platte Center:
discharge measurements 161
Schuyler:
discharge measurement 161
Shobe Branch, discharge measurement of 235
Snake River, dam on, view of 224
discharge measurements on 235
falls of, view of 222
Skunk Creek, discharge measurement of 161
Soldier Creek at—
Fort Robinson:
discharge measurement 241
South Bend,
Platte River at:
description of 55–56
discharge measurements 56, 161
gage heights 56
South Loup River, discharge measurements of 161
at Arnold:
discharge measurement 161
at Callaway:
discharge measurements 161
at Georgetown:
discharge measurement 161
at Ravenna:
discharge measurements 161
at St. Michaels:
discharge measurement 161
South Platte River at—
Julesburg:
discharge measurement 162
North Platte:
discharge measurements 162
Ogalalla:
discharge measurement 162
Sutherland:
discharge measurement 162
Sowbelly Creek, discharge measurements 241
at Bodarc:
discharge measurement 241
Spring Creek (Niobrara River drainage) at—
Mills:
discharge measurement 236
Spring Creek (White River drainage), discharge measurement of 241
Springview, rainfall at 236, 237
Squaw Creek, discharge measurements of 241
Stamford,
Sappa Creek at:
discharge measurement 213

Stinking Water at— Page.
Palisade:
discharge measurements..... 213
Stratton, rainfall at..... 214,217
Republican River at:
discharge measurement..... 213
Sutherland—
Birdwood Creek at:
discharge measurements..... 157
North Platte River at:
discharge measurement..... 160
South Platte River at:
discharge measurement..... 162
South Platte River at—
Big Spring:
description of..... 108
discharge, daily..... 109
discharge measurements..... 108
gage heights..... 108–109
Julesburg:
description of..... 101
discharge, daily..... 104–106
discharge, monthly..... 107
discharge measurements..... 101
gage heights..... 101–104
South Platte River basin, description of..... 99–101
hydrographic data in..... 101–109
Spottedtail Creek, discharge measurement of. 162
Spring Creek, discharge measurements of..... 162
Storage, ground relation of, to run-off..... 25–26
Stout, O. V. P., stream measurement, method of..... 10
Stream measurement, accuracy of..... 17–21
methods of..... 9–17
Stout's method of..... 10–15
Streams, character of..... 10
map showing..... 6
Superior, rainfall at..... 214
Republican River at:
description of..... 183–184
discharge, daily..... 193–196
discharge, monthly..... 198–199
discharge measurements..... 184–185
gage heights..... 186–189, 191–193

T.

Thompson Creek, discharge measurement... 213
Trunk Butte Creek, discharge measurements of..... 241
Turkey Creek at—
Naponee:
discharge measurement..... 213

U.

Union Creek at—
Madison:
discharge measurement..... 162
Units of measurements, definitions of..... 7

V.

Valentine,
Minnechaduza Creek at:
discharge measurements..... 234
Niobrara River at:
description of..... 222–223
discharge, daily..... 227–229
discharge, monthly..... 230
Valentine—Continued. Page.
Niobrara River at—Continued.
discharge measurements..... 20–21, 223, 234
gage heights..... 224–227
rainfall at..... 236, 238
Valley,
Platte River at:
discharge measurement..... 161
Verdigris Creek, discharge measurement of.. 236
Victoria Creek, discharge measurements of... 162

W.

Wallace, rainfall at..... 214, 218
Warbonnet Creek, discharge measurements of 241
Warwick,
Republican River at:
discharge measurement..... 213
Waterloo,
Elkhorn River at:
discharge measurements..... 158
Wauneta,
Frenchman River at:
description of..... 205–206
discharge, daily..... 207
discharge measurements..... 206–207
gage heights..... 206–212
West Middle Creek, discharge measurements of..... 236
White Clay Creek (Niobrara River drainage), discharge measurements of..... 236
White Clay Creek (White River drainage), discharge measurements of..... 241
Whitehorse Creek, discharge measurement... 162
White River near—
Crawford:
description of..... 239
discharge measurements..... 239, 241–242
gage heights..... 239
White River basin, description of..... 239
hydrographic data..... 239–242
Whitetail Creek, discharge measurements of.. 162
Whitney,
White River at:
discharge measurements..... 241
Wilbur,
Big Blue River at:
discharge measurement..... 211
Wilsonville, rainfall at..... 214, 216
Winter, run-off in..... 25
Woodenspring Branch, discharge measurement of..... 236
Woodlake,
Red Deer Lake near:
gage heights..... 232–233
Wood River at—
Glenwood:
discharge measurement..... 162
Wray, Colo., rainfall at..... 214, 219
Republican River at:
discharge measurement..... 213
Wymore,
Big Blue River at:
discharge measurements..... 211

Y.

Yuma, Colo., rainfall at..... 214, 219